Bulletin 68. March, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

ARKANSAS VALLEY SUBSTATION.

PASTURE GRASSES.
LEGUMINOUS CROPS.
CANTALOUPE BLIGHT.

By H. H. GRIFFIN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

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PASTURE GRASSES FOR THE ARKANSAS VALLEY.

BY H. H. GRIFFIN.

For years there has been considerable inquiry in regard to pasture grasses for this valley. The farmer is often heard to remark "I wish I could get something on which to pasture a cow, this alfalfa is so dangerous."

Almost since the establishment of the substation pasture grasses have been tested for their adaptability to this section, but one of which has been reported upon in bulletin form, viz: Bromus inermis in Bulletin 61.

The behavior of other grasses has been reported from time to time in the annual reports but this information is not generally accessible to the public.

Enough data has now been obtained in regard to the adaptability of all of the most important grasses, to warrant publication.

The theory of permanent pastures is a very fine one. Farmers are more and more giving up the idea on lands under irrigation. I believe the farmer can get more feed and much greater returns from the land in a regular rotation of crops. One acre of alfalfa cut and properly fed will keep an animal the year round. With pastures, much more land must be devoted to one animal.

It will not pay the small farmer to devote much land to pasture. There are others having larger farms who do not look so closely to the return per acre, who do desire some grass for stock pasture. Often there are waste lands or tree claims that can be devoted to pasture.

The first work in testing grasses was done in 1891. Mr. Huntley, then superintendent, reports on these in the annual report of the Experiment Station for 1894 as follows:

"Based upon trials of three years' duration, but two grasses out of eight tried, have given promise of enduring field culture for pasture. They are Bromus and Orchard grass. The unsuccessful ones were, Hard Fescue, Meadow Fescue, Perennial Rye grass, Italian Rye grass, Red Top and Blue grass. It is quite probable some of these would succeed in moist soils of other localities in the state."

The report for 1895 mentions only the Bromus and Orchard grass as making good showing that season.

The varieties tested in addition to those above mentioned since the writer took charge in 1898 are, the Tall Oat grass and Meadow Fescue (*Festuca elatior*) sometimes called English Blue grass.

Bromus inermis has been quite extensively reported upon in Bulletin 61 and the reader is referred to it for information. It may be said that the results in 1901 confirm the report made of it in bulletin 61.

Orchard grass, Tall Meadow Fescue, Tall Oat grass and Blue grass comprise the list of grasses that may be profitably grown here for pasture.

ORCHARD GRASS. (*Dactylis glomerata.*)

This grass is uniformly successful in the Arkansas valley, whether sown on the dry uplands, in timber claims or in moister lands. It is a tall grass growing in clumps but is valuable for either pasture or hay. It may be sown profitably with alfalfa. It matures with the first crop and would improve the quality of the hay for feeding horses.

This grass is easily started and does not need nursing to get it established; it resists drouth and hot weather well. It is one of the first things to appear in the spring. When pastured off, it soon starts growing again.

Owing to its nature to grow in tussocks, it is advisable to sow some other grass with it to occupy the intervening spaces. Either the Tall Oat grass or the Tall Fescue is adapted to the purpose, preferably the latter.

Orchard grass, like many others here, does not fail to grow some during the hot weather. It also stands irrigation well, not becoming sod bound.

About 25 pounds of seed per acre should be sown.

TALL MEADOW FESCUE. (*Festuca elatior.*)

This grass is sometimes called English Blue grass. In ordering the seed of this grass it must not be confounded with another grass called Meadow Fescue (*F. pratensis*) in the catalogues.

The latter kind has never been successful at the station.

Tall Fescue has not been under trial so long as the Orchard grass but its value has been fully demonstrated to the uplands of this section. It forms a thick vegetation and is so persistent as to gradually thicken up; the seed shoot growing about two feet in height.

Reports from the Kansas Experiment Station speak well of it.

It is a valuable grass in the Arkansas Valley; alone, or in combination with others.

Sow about 25 pounds of seed per acre.

TALL OAT GRASS. (*Avena elatior.*)

This grass is largely grown in the southern states where it is highly valued.

It does well in this valley but does better if sown in mixture with Orchard grass. It has been difficult to get a good stand of this grass owing to the poor germinating power of the seed.

This grass will remain partially green nearly all winter and will commence growth very early in spring.

All reports of this grass with which I am familiar give it very high nutritive qualities. At least two bushels of seed should be sown per acre.

KENTUCKY BLUE GRASS. (*Poa pratensis.*)

Climate has much to do with pasture grasses. It is a well known fact that Blue grass cannot stand hard use and long continued dry hot weather. It is said "whoever has limestone land has Blue grass," and while we have plenty of lime in the soils of this section, yet Blue grass cannot be relied upon for pasture, owing to the vast amount of irrigation it requires to keep it thrifty. Nearly everyone is aware how much irrigation this grass requires when it is grown for lawn, which is sufficient demonstration that under but few conditions can it be relied upon for pasture.

Lands having considerable clay or adobe with an abundant water supply will produce this grass in sufficient quantity to make good pasture. But put under conditions where it must withstand drouth it will perish at a time when Orchard grass or Tall Fescue would be in good condition.

In most instances it will require considerable nursing to secure a stand and it is only when ornament and utility are both desired that it is advisable to grow Blue grass for pasture.

RED TOP. (*Agrostis vulgaris.*)

This grass has not been a success on the dry upland soils of the station.

I see no reason why this grass should not succeed upon some of the moist low lands and sub-irrigated lands of this valley. The writer has seen this grass succeed in other localities under similar climatic and soil conditions to those above mentioned.

TIMOTHY. (*Phleum pratense.*)

Timothy is not a success on the uplands and it can hardly be said to be on any lands in the valley.

I do not believe the returns will warrant sowing it at all.

WHEN TO SOW GRASS SEED.

There are two times of year only when grass seed may be sown with good success in this country, viz: March and August.

By sowing in the former month, the grass gets a start before the weeds come on to choke it out and besides it will sometimes get the benefit of April storms.

In many respects August is the preferable time to sow. There are no weeds or foreign grass to choke the young grass. The weather becomes cooler and damper and the young plant receives the benefit of summer rains that usually occur.

The plant gets well established before winter and starts the next spring strong and vigorous to take possession of the land.

If sown in August, the farmer may take a grain crop from the land previous to sowing, but if the grass is sown in the spring the season is lost for anything but the grass.

FALL SEEDING OF ALFALFA.

Sometimes conditions of crops and labor are such that the farmer wishes to sow alfalfa in the fall. He wishes to know if it may be done with impunity.

In the first week of September 1898 the station sowed three acres to alfalfa. This was just preceeding the severe winter of 1898-99 in which the thermometer registered $-32°$. A good rain came soon after the seed was sown and the seed came up nicely, the plants getting about two inches high when winter set in. A few spots died out during the winter but the greater part of it stood the extreme cold weather well.

The weather conditions that winter were the worst ever recorded in this country and the results seem to indicate that alfalfa may be sown in August or early September with impunity.

The rules given for the sowing of grass seed hold good in regard to the sowing of alfalfa seed.

LEGUMINOUS CROPS FOR THE ARKANSAS VALLEY.

BY H. H. GRIFFIN.

For three seasons the sub-station has been testing leguminous plants to ascertain what may be expected of them in this valley. The main object has been fertility, but incidentally their value for forage, for bees and mulch or cover crops for the soil.

The plants under investigation are the Serradella, Red Clover, Cow pea, Field pea, Soy bean and Hairy vetch.

SERRADELLA. (*Ornithopus sativus.*)

The Station failed to secure a single plant of this legume. The writer has seen other trials in the arid region with this plant but has never seen them successful. The plant does not seem to be adapted to arid conditions.

RED CLOVER. (*Trifolium pratense.*)

This legume does not thrive under our arid conditions. However, in old orchards where there is partial shade, or in open fields where the soil is rather heavy and water supply abundant, some success may be secured with Red Clover.

To be of much value as a fertilizing plant it must occupy the land for at least three years and as there is not much revenue from it in the interim, it becomes an expensive plant to grow for field fertilizing.

The only place for which we can recommend it at all is old orchards and it is doubtful whether it is advisable to use there, as there are other plants better adapted to our conditions.

COW PEA. (*Vigna catjang.*)

This is a valuable plant for the Arkansas Valley. The Station has tested the Whipporwill, Black, Clay and New Era varieties. The former we consider the most desirable owing to its upright growth. This variety will ripen if sown as late as the last of May.

As high as two tons of hay per acre have been cut on land devoted to this plant, besides leaving a considerable

quantity of vegetation to be incorporated with the soil. The roots are well supplied with tubercles. It will produce from 6 to 10 bushels of seed per acre, which is relished by poultry or hogs, and about two tons of hay.

The New Era variety will mature seed in about one month less time than the Whipporwill and may meet a demand for late sowing in orchards. It does not grow nearly so rank as the Whipporwill.

This plant should be sown in drills from 22 to 32 inches apart. The work may be done by a grain or beet drill. One or two early cultivations should be given, after which it will cover the ground. This plant can be sown as late as the first of July where intended only for fertilizing purposes. It is a splendid plant to sow in orchards to relieve the trees from the reflection of the sun in late summer, winter and early spring, after which it may be plowed under as a fertilizer.

Two plats, one-tenth acre each, that produced Cow peas in 1900, were devoted to the growth of beets in 1901. The peas were cut with a mower so that only the roots and stubble remained to plow under. Two plats of the same size that had never been fertilized, and which had grown crops similar to those on which the Cow peas were sown, were planted to beets also for comparison. Both plats were given the same treatment. The plats on which the Cow peas had been grown yielded 16 tons per acre, the other plats yielded 12.5 tons per acre. That the nitrogen supply was augmented by the growth of the peas was apparent from the color and vigor of the beet tops.

THE FIELD PEA. (*Pisum arvense.*)

The Field pea does fairly well at Rocky Ford if sown very early in spring, so that its growth may be made before the approach of hot weather.

The seed should be sown the latter part of March. The peas will ripen the first week in July.

The yield on the Station grounds in 1901 was 23 bushels from two acres. The yield in 1899 was at the rate of 16 bushels of seed per acre. In addition to the yield of grain there was produced at least 3 tons of splendid feed on the two acres. The above returns are only medium, for in neither case were the conditions such as to give the best returns

The variety grown in 1899 was the "Mummy;' that grown in 1901 was the "Marrowfat." I consider either of them preferable to the Canada pea for this section.

This pea may be sown with oats early in the spring; the product cut for hay late in June and the ground devoted to some other nitrogen gathering crop for the remainder of the season.

From 100 to 120 pounds of seed should be used per acre. I think the most desirable way to cover the seed is to plow it under.

THE SOY BEAN. (*Glycine hispida.*)

The Soy bean is an upright, bushy, leafy plant growing about 3 feet high and requiring about 100 days to mature.

The station has grown the Early Yellow and the Medium Early Green.

The bean of this plant is extremely rich in protein and is especially desirable for combining with corn or sugar beets for pork production. When utilized this way no threshing is required.

The Kansas Experiment station has made some extensive experiments with Soy beans in combination with other foods (especially Kaffir-corn) for feeding pigs. The results are reported in Bulletin 95, and show a gain of 96 per cent. by the substitution of one-fifth Soy bean meal to a Kaffir-corn ration.

This plant resists drouth well; the Kansas station claims it is fully equal to Kaffir-corn or sorghum in this respect.

The Soy bean may profitably be grown under many ditches with scant water supply, in place of corn, especially if the soil is rather light and needs improving in fertility.

The seed should be sown with a grain or beet drill about the middle of May, putting the rows from 22 to 32 inches apart. About 40 pounds of seed per acre is required. The yield ranges from 10 to 25 bushels per acre. The harvesting should be done before the pods begin to turn yellow or great loss will ensue from the popping open of the pods. But one crop can be grown in one season on land devoted to this bean, owing to the time required to mature it.

Land devoted to Soy beans in 1900 and planted to sugar beets in 1901, gave as high as 6 tons greater yield than adjacent land having no fertilizer applied.

HAIRY VETCH. (*Vicia villosa.*)

Hairy Vetch is known as Sand, Winter, or Russiar Vetch.

Some of the farmers of the Arkansas Valley have expressed their desire for a plant that may be sown in the fall, after taking a crop from the land, and make sufficient growth to turn under in the spring, thus adding fertility to the soil.

Hairy Vetch meets this demand admirably. It will make growth in this valley during all but the severest part of the winter. It makes its poorest showing during the heat of summer. For this reason it is preferable to sow in late summer or fall.

The station has secured good results from sowing as late as October first.

In one instance the seed lay in the soil over winter and germinated with the first approach of spring; the plants produced seed in July, but of course the results are not so good as where the plants become well established before winter.

The Hairy Vetch will thrive on the lightest kind of sandy soils and where sown in the fall, will keep such lands from blowing during the spring months, afterwards adding a vast amount of humus and fertility to them. The roots are bountifully supplied with tubercles. If this plant is sown in early September it will produce a considerable growth to plow under in April or May, or if allowed to ripen will do so in early July. It will bloom, about the middle of May and from that time on until it ripens is a vast profusion of bloom. Bees frequent it in great numbers, seeming to do so to the exclusion of most other plants. Early fall sowing makes splendid pasture during April and May, and if the plant is started in the summer it will furnish pasture in February or March.

Six-sevenths of an acre was sown to this seed, August 11, 1899. By May 12, 1900, it stood two feet high and commenced to bloom. The seed was ripe the first week in July, at which time it was cut.

The yield of straw was 3000 pounds, which yielded 400 pounds of seed. July 26, the same land was prepared by a disc harrow and watered, and from the seed that scattered off, a good stand of the vetch was secured, which was allowed to grow until April 1901, when it was plowed under and the land seeded to beets.

Two acres near by were given a dressing of ten loads of sheep manure per acre and one acre was left without manure as a check.

The tops of the beets on the vetch land grew rank and thrifty, having the dark healthy green and much of the appearance of beets on alfalfa land.

The results show a heavier yield than was obtained from the use of manure and as much as 50 per cent, increase over the land not fertilized.

Trials in 1901 show further, that the vetch may be sown with oats and be cut with them for hay in July, after which it will produce seed.

This plant may be sown in orchards late in summer and make a splendid cover crop to overcome reflection from the snow in winter and early spring, after which it may be plowed under, adding much fertility to the soil.

The plant is easily destroyed and in no sense will become a nuisance.

It is already apparent that the farmers of the Arkansas Valley must fertilize and rotate crops if success is to be obtained. The larger farms are being more and more cut up into smaller ones.

On small farms alfalfa cannot be grown to advantage; it takes too long to get it established and after it is well established, it is difficult to eradicate.

The small farmer should get the best possible results from his farm, and if leguminous crops can be so combined that he may take two crops from the same land in one year, they will be of profit to him.

The following outline will briefly show how some of the crops above mentioned may be combined as fertilizers: Field peas may be sown early in spring with oats and cut for hay the latter part of June. The ground may then be planted to Mexican beans.

Field peas may be sown early and allowed to ripen seed, after which the land may be devoted to Cow-peas which may be either turned under or cut for hay.

Hairy Vetch may be sown in the fall and plowed under in the following spring. Mexican beans or Cow-peas may follow it.

Cow-peas may be sown quite early in the spring and cut for hay, after which the land may be sown to vetch and the growth turned under the following spring.

By some such system of cropping as outlined above, the farmer can make his supply of yard manure do much greater service.

The above mentioned crops will enter nicely into a 3 or 4 year rotation with cantaloupes, beets or tomatoes.

CANTALOUPE BLIGHT IN 1901.

BY H. H GRIFFIN.

Bulletin No. 62, gave full information of our results looking to the control of the cantaloupe blight, closing with the season of 1900.

The work in 1901 was planned as follows: To treat the seed with Bordeaux mixture to control the blight; to determine at what stage of growth the spraying should be done to be most efficient

The work attempted on the station grounds was destroyed by a hailstorm the 24th day of July. Some knowledge was gained of the efficacy of early spraying in a field belonging to a Mr. Dixon. He had sprayed one part of his field twice and another part three times. The first spraying was done when the vines had started to run slightly. The second spraying was done about the time the melons were setting on the vines, the third about the time picking for market commenced.

At the time I saw the field (first of September) there was a marked difference in the vines in the two lots. Those sprayed early (hence had the three sprayings) were in much the better condition, and Mr. Dixon said the melons were of better quality. Mr. Dixon has used the Bordeaux spray for two seasons and is very enthusiastic over the benefits to be derived from its use for control of cantaloupe blight.

Another field that was given one spraying late in July, was thrifty and bearing splendid melons (August 26) when fields across the fence had been abandoned for ten days, both fields having produced melons the previous year.

The sprayed field was also near two fields of melons growing on alfalfa sod that about September first were apparently in the best of condition. By Sept. 18th, the fields on the alfalfa sod were almost destroyed by the blight, while the sprayed field remained in quite good condition and was yielding melons of good quality. The sprayed field of 14 acres, yielded 3300 crates of marketable melons Mr. Crum, the owner, after two years' trial of the spray, is well pleased with the results.

After the destruction of the vines on the station grounds a part of an adjoining field was sprayed. This had been

heavily manured with sheep manure and was planted the last of May. The work was done July 30th, at which time the vines were almost covering the ground.

About the 25th of August, the blight was making rapid progress in all melon fields. The benefit derived from the spraying in this field was especially well marked. About Sept. 1, the unsprayed vines were giving up fully twice as many melons per day as the sprayed vines. The latter were ripening somewhat as they would under normal conditions, but the others, both vine and fruit, were deteriorating rapidly.

A portion of a field on the station that was planted the first of June, and which recuperated after the hail, was given two sprayings, one late in September and again about ten days after. The results confirm the results given elsewhere in regard to the efficacy of the Bordeaux for the control of the blight.

That nothing but fresh lime should be used in the preparation of the Bordeaux was especially emphasized in this work. We used some air slaked lime, as it happened to be at hand, and a portion of the vines were badly injured by the spray, giving them much the appearance of a bad case of blight. There was one significant feature of this, the vines that were apparently badly injured by the spray recuperated and looked well afterwards, while those attacked by blight grew worse.

There is evidence that the blight is more than a local trouble. The writer happened to visit some melon fields in the vicinity of Brighton, about September first, and there saw the blight doing serious injury. Reports and specimens of melon leaves sent me from Grand Junction indicate that the disease is well established there. The observations of this year verify those of last year in that the disease is well distributed over the entire Arkansas valley. Both the farmers and the shipping agents realize that the trouble is a serious one and are considering its consequences. That the trouble was only temporary is no longer held as a tenable opinion, but rather one demanding such treatment as will lessen its ravages.

The weather conditions have been the most favorable for a study of the disease of any I have ever had in that it was more of a typical season. Two of the former seasons were extremely wet during July and August and that of 1900 was very dry. The rain of the last season was moderate in amount and well distributed. Two features were prominently brought out this year. One was to avoid the use of any heating manure previous to planting melons and the

other was the necessity for rotation of other crops with cantaloupes. A comparison of cantaloupe fields in close proximity, some of which were on alfalfa sod, some on grain land and others on cantaloupe ground, revealed the great benefits to be derived from the use of the alfalfa land. Land that had been in melons for a number of years showed the blight in about the same ratio as the number of years to which the land had been cropped to melons. Heating sheep manure is especially undesirable to precede melons.

I had under observation, this year, one field in which the seed had been planted March 28. April 18 the seed was practically in the same condition as when planted. April 27 the seed was irrigated; many of the seed sprouted but no plants up. May 8 some of the plants were up and had the third leaf, others were just coming up, while about one-third of the field had to be replanted. The first ripe melon was taken July 27.

Comparing this field with others the conclusion can be aptly drawn that had the planting been done one month later the results would have been fully as good, if not better Last Spring was one of the most favorable of springs for extremely early planting.

EXPRESS BOOK PRINT
FORT COLLINS, COLO.

Bulletin 69. March, 1902.

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PLANT DISEASES

OF 1901.

—BY—

WENDELL PADDOCK.

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PLATE I.

Apple trees killed by too much water and root rot.

PLANT DISEASES

OF 1901.

By WENDELL PADDOCK.

INTRODUCTION.

A brief account is given in the following pages of some of the plant diseases which have come to our attention during the past season. Only a few of these were brought to our notice by correspondents, and it is the purpose of this bulletin to stimulate a greater interest in the subject, for it is reasonable to suppose that these pests of our crops will increase in Colorado as they have done in older States. By prompt attention many of them may be overcome or controlled. In a State so large as ours it is impossible for one or two men, with the time at our disposal, to visit very many different localities. It is, therefore, desirable in the interest of all that any untoward condition of crops, be it due either to insects or fungi, should be reported to the Experiment Station. Specimens of the affected plants should in all cases accompany the report.

Now a word as to the nature of plant diseases. This term is commonly applied to a class of plants known as fungi, and sometimes to the result of unfavorable soil or atmospheric conditions, but rarely to insect attacks. The following pages have to do mostly with fungi. These plants are low in the scale of development and are mostly of microscopic size, though some of them, as toad stools and puff balls, are familiar objects. Plants of this class are unable to take nourishment from the soil, consequently they must live on food that has been prepared by other plants. Many of them live on decaying vegetable matter, but others are true parasites, attacking live plants and thus becoming of economic importance. These tiny plants have organs that correspond to the roots, branches and seeds of higher plants.

The seed-like organs or spores, go through a process of germination much the same as a grain of corn. Being so small they are readily borne about by the wind and when they chance to fall on the kind of plant to which the fungus is adapted—its host plant—and the conditions are favorable for germination, the fungus readily gains a foothold.

It has been found that spores are unable to germinate in the presence of small amounts of copper, and advantage is taken of this fact when plants are sprayed with Bordeaux mixture. The copper in the mixture protects plants, hence the better the spraying is done the more complete is the protection. The fact that Bordeaux is not a cure should be borne in mind, and to be a successful preventive it must be applied before the spores are disseminated.

Fungi that live in the soil and attack the roots of plants are not dependent on spores as a means of dissemination. The root-like organs, or hyphæ, spread through the soil from plant to plant, or they may be distributed by the cultivator or other means. With root diseases the treatment is more complicated, since there is usually no way of telling that a plant is affected until it is past recovery. A systematic rotation of crops is often of help in keeping annual and biennial plants healthy, but with orchards little can be done after the trees are attacked. Good care in every respect will be a great aid in keeping the trees free from disease.

Many of the fungi which produce disease in plants are invisible to the unaided eye, hence they are apt to be regarded as something mysterious and the effects are often ascribed to other causes. The action of climate, altitude, winter injury, alkali and water are often mistaken for the effects of attacks of fungi. For example, the potato failures in the vicinity of Fort Collins have long been thought to be due entirely to peculiar conditions of soil and climate, notwithstanding the fact that the famous Greeley potato district lies only twenty miles east and in the same altitude. Experiments conducted at this station during the past year prove that the lack of success is due primarily to root diseases which thrive much better in our heavy soil than in the lighter and better drained soils in the potato district. The fact that we have occasional successes here is no doubt largely due to planting clean seed in soil that is free from disease, or the conditions are not suitable for the best development of the fungi during certain seasons.

APPLE TREE ROOT ROT.

The presence of an unusual amount of yellow foliage on fruit trees last spring attracted attention in various localities in Northern Colorado. It is a well known fact that too much water will produce yellow foliage, and this is the cause that is commonly thought to be accountable for this condition. As the leaves usually regain their normal color before the close of the season but little attention is given to the subject. An unusual amount of rain in the early summer was probably the cause of this general appearance of yellow foliage, but many fruit growers have noticed that occasional trees are affected in this manner year after year and finally die without any apparent cause, while adjacent trees remain healthy. It is not

PLATE II.

Winter injury of apple trees induced by peculiar soil conditions.

PLATE III.

Blackberry roots injured by Rhizoctonia. Natural size.

uncommon for such trees to die in the latter part of summer, when the fruit and foliage wither and cling to the dead branches. Such trees are usually comparatively loose in the soil, in fact, some of them may be tipped over while they are yet alive. Upon examination the larger roots will be found to be in an advanced stage of decay, and the feeding roots finally become so reduced that there are not enough left to support the tree.

Certain fungi are constantly associated with the diseased roots, and it is probable that they are ultimately responsible for the death of the tree. As a result of numerous examinations, it was found that these same fungi also attack the roots of trees that are apparently healthy. Now it is easy to conceive that these diseases may live on the roots of a tree for a number of years without doing much harm, but as soon as the tree is weakened from any cause the fungus makes rapid advance.

Trees that take on yellow foliage from overirrigation suffer a temporary check in growth, from which they apparently recover in a short time. But if this is repeated year after year the ultimate effect must be very injurious. A wet, heavy soil, however, produces ideal conditions for the growth of root destroying fungi which appear to be abundant in our State, and when a favorable opportunity occurs they become destructive.

Winter injuries, which result in sun scald, black heart, freezing of the roots and dry freezing of both roots and branches, are potent causes of the weakening of the vitality of trees in some sections of the State. Trees may be injured in some one of the above ways and yet not show any marked indication that anything is wrong.

A good deal of damage is also done to fruit trees by the attacks of wooly aphis, which are abundant in many localities. They increase rapidly if left undisturbed, and the greater portion of the root system may soon be infested. These conditions result in serious injury and trees may even be ruined by such attacks. Root fungi are not slow to take advantage of the enfeebled roots, and it is likely that in many instances they rapidly extend these injuries.

In some localities the natural drainage of the soil is poor, and it is evident that too much water is being used in irrigating. In a number of orchards visited the level of the water in the soil had been raised till the lower roots of the trees were apparently surrounded by a saturated soil most of the time. This is particularly true of small orchards, where the owners grow small fruits or truck crops between the rows to supplement the income from the orchard. Root fungi thrive remarkably well under these conditions, and the combination of causes is doing no small amount of damage. One orchard came under my observation where all of the trees on an area of about two acres had been ruined. (See Plate I.). Another orchardist reports a yearly loss of about 25 out of an orchard of 1,000 trees. Instances of this kind might easily be multiplied.

That the trees are injured by water under these circumstances cannot be doubted, since no agricultural plant can thrive in a saturated soil. We have not yet demonstrated the exact relation which fungi bear to this condition, but it is evident that they play an important part in the destruction of the trees. Certain species are usually found on the roots of diseased trees and attacking healthy tissue. Moreover, young trees have been known to be killed in one season, apparently by root rot, when planted in the places from which dead trees had been removed.

This subject is a most perplexing and important one, and one that is as yet but little understood. We expect, however, to make it one of the principal lines of investigation of this Section for the coming season. In the meantime certain sanitary measures may be mentioned that might well be observed by many orchardists.

When it becomes evident that too much water is being used in irrigating, as is indicated by yellow foliage, or by the raising of the level of the water in the soil, more use might well be made of the cultivator. By keeping the surface of the soil loose much of the water is prevented from evaporating, thus lessening the necessity of frequent irrigation. The trees should be kept in a thrifty condition, and yet not allowed to make a rapid growth, which produces soft tissues that easily succumb to attacks of blight. On some soils it may be best to keep the orchard seeded to alfalfa, but usually better results will follow a systematic use of cover crops. The many advantages to be derived from the use of cover crops cannot be discussed here, but with this system of cultivation some crop is sown in the orchard in late summer or early fall which is plowed under the next spring. Mr. Griffin has found that the best leguminous plant for this purpose at Rockyford is hairy vetch. (See Bulletin No. 68 of this Station). Since this plant is one of the nitrogen gatherers it may not be advisable to use it on all soils; in such cases winter rye may be used instead. In localities where the attacks of blight are severe, it may be advisable not to plow the crop under till late in the spring and thus avoid a rapid early growth of new wood.

APPLE TREE ROSETTE.

A peculiar condition of apple trees was brought to our attention on Rogers Mesa in Delta county by the Horticultural Inspector. More or less of the trouble occurs in a number of orchards in this locality, consequently it is a matter of considerable interest in the county. Some of the trees are dying, while there are a number of dead limbs on others, but the characteristic feature of the disease is a tuft or rosette of small leaves at the end of branches that are otherwise nearly bare of foliage. (See Plate II.). The similarity of this condition to the peach tree rosette, a common disease in portions of

the Southeast, was so great that the presence of a new apple tree disease was suspected.

I visited this section in July and collected numerous specimens, but no parasitic organism could be detected by laboratory investigation. Later on Mr. C. H. Potter visited some of these orchards and made valuable observations on the soil formation. I visited the locality again in September in company with Dr. Headden, and as a result of our observations and study, together with the experience of the fruit growers, we arrived at the following conclusions:

Much of the soil on the Mesa contains an excess of marl and in many places this substance forms a solid substratum. At the edge of one orchard visited the owner was digging and burning it to make a cement to be used in mason work. The marl in itself is, perhaps, not harmful to plants; in fact, when judiciously applied to land it acts as a liberator of plant food, but when present in excess the soil is infertile. This is shown by the fact that when roots penetrate the marl substratum they send out few or no fibrous roots. The roots do not usually penetrate this substratum to any extent, consequently the trees are often shallow-rooted in orchards where the layer of marl is close to the surface. The level of the lowest roots on one dying tree was only ten inches below the surface of the soil. At this depth they branched out horizontally, where they were readily injured by lack of moisture and by the action of frost. But a more immediate cause for this condition of the trees is found in the water supply. Water is plentiful during the early part of the season, but in the latter part of June the supply has usually been exhausted. The nature of the soil is such that it readily dries out and the trees suffer for moisture, consequently growth stops and the tissues harden. In the latter part of July a partial supply of water is again turned into the ditches and the orchards are irrigated. The result is that in many instances these trees make a distinct second growth which is immature when cold weather comes on. Those branches which are not killed outright but are severely injured during the winter put forth a feeble growth the following spring. The end bud, usually being the strongest, lives at the expense of the others, consequently many of the side buds soon die if they start into growth at all, and the terminal one develops a contracted branch on which the leaves are crowded, thus forming the rosette.

Second growth is not always necessary, however, for the appearance of this disease. Shallow-rooted trees planted in a soil that is quickly dried out are easily injured during the winter. This probably accounts for the fact that the disease first attracted general attention after the hard winter of 1898-99.

One orchard was visited in which a small number of diseased branches had appeared, but which had been promptly removed or severely cut back early in the spring. At this date, October 5, the

trees appeared to be perfectly healthy and had made a vigorous growth which showed no sign of disease. This experiment tends to confirm the conclusion that the difficulty is due to local conditions and not to a specific organism which might spread to other portions of the valley.

Apparently the same difficulty is figured and described in a recent *California bulletin in which the author ascribes the cause to the presence of alkalies in the soil. He states that apple trees are injured "by 1,200 pounds of carbonate and 3,000 pounds of common salt per acre distributed through four feet depth."

The particular soil on Rogers Mesa that was examined contained 1,820 pounds of common salt per acre taken to a depth of one foot. While this is a much larger amount of salt than the trees are said to be able to endure in California, most of the trees do not show any sign of the affection, though they have been planted nine years. This statement is confined to the first foot of soil, because it is doubtful if there is any portion of the orchard where the soil is four feet deep. Moreover, the subsoil is a marl into which the trees had thrown very few roots.

The amount of sodic carbonate in this soil was not determined. However, we have had occasion to observe a nursery that was established in a soil in which the sodic carbonate content was determined and found to be 2,800 pounds per acre, taken to a depth of four feet. The trees made an excellent growth for three years and showed no sign of the rosette affection.

While these observations do not prove that this condition of apple trees may not be produced by the action of alkalies, they point to the conclusion that such an effect is improbable under our conditions.

Treatment.—Apple trees should not be planted on soil where the marl substratum comes close to the surface, as it will result in shallow-rooted trees with its attendant evils. In other portions of the district an attempt should be made to make the soil deeper and to add to it substance and fiber. Many Colorado soils are deficient in vegetable matter, consequently they become compact and dry out rapidly. Depth may be gained by plowing deeply before the orchard is planted, and vegetable matter added by turning under strawy stable manure or green manure. For the latter purpose some form of clover, vetch or rye may be used, preferably in the form of a cover crop, which should be sown in the latter part of summer and plowed under during the following spring. If water for fall irrigating is available the crop will make growth sufficient to afford considerable protection to the roots against the action of frost and from drying out by winter winds. Finally, by a judicious use of water, of which

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*Laughridge, R. H. "Tolerance of Alkali by Various Cultures." Calif. Agri. Expt. Sta. Bull. 133:14.

PLATE IV.

Fig. 1. Cherry tree injured by mound parasite.
Fig. 2. Detail of apple limbs shown in Plate II.

PLATE V.

Fig. 1. Spore pustules of rust fungus on branch of Asparagus. Enlarged.

Fig. 2. Aster killed by Fusarium.

Fig. 3. Raspberry leaves curling at edges. The result of an attack of Rhizoctonia on the roots.

an abundance is promised the Mesa for the coming season, it is not likely that this disease will be very injurious on soils that are of sufficient depth to make suitable orchard land.

APPLE INJURY FROM SPRAYING WITH BORDEAUX MIXTURE.

Complaints were received from correspondents at Canon City and Montrose that spraying with Bordeaux mixture had seriously injured the fruit of certain varieties of apple trees. The injury produced is well shown in the illustration in Plate VIII., Fig. 3, which is from a photograph of a Ben Davis apple that is so disfigured as to be unsalable. This variety appears to be very susceptible to such injury, though a number of other kinds were injured more or less. All degree of disfigurement occurred, from a slight russeting of the skin to the malformation shown in the figure.

That the corrosive action of Bordeaux mixture is responsible for this condition there can be no doubt. The subject has attracted considerable attention in the Eastern States, where it has been found that such injuries are much more common in some seasons than in others. Just what the conditions are that favor this action of the mixture have not been determined and the subject is still in an experimental stage. This is particularly true of the arid regions, since fungicides are just beginning to be used here on fruit trees.

In the light of our present knowledge, it can only be recommended that great care be taken to see that the mixture is properly made. The formula on a subsequent page has been found to be sufficiently strong for combating fruit-tree diseases as they occur in other States. Further experience with spraying in Colorado may show the necessity of modifying the formula to suit our conditions. And, finally, Bordeaux mixture should not be used unless it is needed. In the vicinity of Canon City it is said that the bitter rot of apples is abundant and the orchardists sprayed their trees with the mixture for the purpose of combating this disease. But in the majority of the fruit growing districts apple trees are not yet affected to any extent by such plant diseases as can be controlled with Bordeaux mixture.

BLACKBERRY ROOT DISEASE.

(*Rhizoctonia.* Sp.)

There was a noticeable amount of light green or yellowish foliage on the blackberry and raspberry plants in the College plantation last spring, which did not regain its normal color. Later in the season leaves on occasional plants began to curl and shrivel as though suffering for moisture, and some of the plants died. Appar-

ently healthy plants exhibited this latter symptom. (See Plate V., Fig. 3). Upon examination, the bushes were found to be attacked by a root fungus which is closely related to the one which is so destructive to potatoes. (See Bulletin No. 70 of this Station). All parts of the plant below ground were attacked, but the greatest injury occurred on the canes above the crown. Here, as shown in the illustration in Plate III., the bark was discolored and shrunken from the crown to the surface of the soil, or a short distance above. The fungus grows on and within the bark, destroying the tissues, and thus interfering with the movement of plant food. The injury commonly extends around the cane, and when it becomes deep enough to cut off the supply of moisture and food, the plant dies.

The presence of the yellowish foliage was probably due to a badly diseased root system at the beginning of the season. An excess of moisture in the early part of the season was favorable to the growth of the fungus, which made rapid inroads on the plant's vitality. That they were poorly nourished, was indicated by the yellow appearance of the leaves.

The drying up of leaves on apparently healthy canes may have been due to a vigorous attack of the fungus which, because of favorable conditions, was able to seriously injure the plant in a short time.

This fungus, *Rhizoctonia*, is destructive to a great variety of plants, and it is widely distributed in the State. There are possibly several species of the fungus, which may be destructive to different plants. Little is known about the disease, and some investigators regard it as a sterile fungus, or one that produces no spores. But our investigations indicate that *Rhizoctonia* is but a stage in the development of a fungus of which some species are well known under another name.

There is no way of curing diseased plants, nor a practical means of preventing the disease from spreading after it makes its appearance in a plantation. It is a wise precaution to destroy all affected plants, but even this severe measure will not rid the soil of the fungus. New plants filled in such vacancies are liable to become diseased in a short time. It has not been determined how long the fungus will persist in the soil, but a new plantation should not be set on land where diseased plants have stood for at least four years.

It is undoubtedly the same fungus which attacks both blackberries and raspberries, hence raspberries should not be set on land where diseased blackberries have recently been grown, or *vice versa.*

Finally, when setting a new plantation, great care should be taken to get plants from stock that is known to be free from the disease.

CHERRY TREE WOUND PARASITE.

Mr. Hankins, Horticultural Inspector for Larimer County, called my attention to a disease of cherry trees in an orchard at Berthoud, where about fifty trees in a young orchard of sour cherries had been destroyed. All of the badly diseased trees then remaining were found to be injured on the trunks, similar to those shown in the illustration in Plate IV., Fig. 1. Large areas of bark had been destroyed which were still clinging tenaciously to the wood. The larger wounds were conspicuous, and when the dead bark was removed, as shown in the figure on the left, it was plain that these injuries were the cause of the death of the trees. In some instances, the trees were nearly girdled, but where the injury was of less extent, the loss of the bark, together with the drying out of the exposed wood, had interfered with the nutrition enough to kill the tree. All other parts were in normal condition.

The owner informed me that the orchard had been neglected and the trees bruised by careless hands while it was in charge of a renter. It is likely that such wounds afforded entrance to some fungus which belongs to a class known as wound parasites. These fungi are unable to penetrate living bark, but when they gain access to the tissues through a wound they are able to entend the injury. On examining closely, an abundance of white hypha was found beneath the dead bark, but what part the fungus took in the injury, if any, has not been determined.

Some neglected trees in the vicinity of Fort Collins were found which showed similar symptoms. These trees had been torn by wind and bruised by hail, thus producing wounds through which fungi could enter readily.

The loss of trees in the younger orchard would probably not have occurred if greater pains had been taken in cultivating. When wounds are accidentally or necessarily made they should immediately be protected by a coat of thick paint or grafting wax. By taking such precautions it is not likely that this disease of cherry trees will cause much damage.

ASPARAGUS RUST.

(*Puccinia asparagi*).

A portion of an asparagus plant, as shown in Plate V., Fig. 1, affected with rust, was received in October from a gentleman at Rockyford. This is probably the first time that this fungus has been reported from this State, and while it has done but little damage as yet, its presence here is of importance, as it has done a large amount of injury to asparagus plantations in other States. In some localities, where many acres of asparagus were formerly grown,

the crop has been practically abandoned because of the ravages of this disease.

The fungus has three stages in its development which appear at different times during the season. The form which usually attracts attention first comes on the canes rather late in the season, when numerous dark brown pustules are pushed out through the bark. These pustules are composed of masses of spores, as are also the dark streaks and patches of a still later stage, which also form on the canes.

These last spores remain on the brush or fall to the ground, where they are ready to spread the disease by attacking the new shoots the following season. The fungus lives within the tissues of the plant, and where badly affected the plant is so weakened that but little food is stored for the succeeding crop. This results in a reduced yield, and if the disease is not checked the bed becomes unprofitable and many of the plants are killed.

By way of prevention it has been suggested that the tops of the plants be cut off and burned early in the fall before the spores fall to the ground. This method has the disadvantage, however, of being injurious to the plants, as in order to be effective the tops must be removed before the plants are matured. This process may injure the plants nearly as much as the fungus.

* Sirrine reports flattering results in combating the disease on Long Island by spraying with a resin-Bordeaux mixture. (See formulas). He expresses doubt, however, whether this method will always pay, since the applications must be frequent and very thorough, thus involving considerable expense. In these experiments from three to five sprayings were given, beginning in July after the cutting season was over. In the case of small beds it will no doubt be a better plan to destroy the plants and start anew on uninfested soil.

ASTER WILT.

(*Fusarium.* Sp.)

The asters on the College campus were nearly all destroyed last season by a species of *Fusarium*. (See Plate V., Fig. 2). The plants appeared vigorous and gave promise of abundant bloom up to the time the blossoms were beginning to open, when many of them began to wilt and in a few days were dead. In no instance, so far as noticed, were isolated plants affected; in some beds all of the plants were killed, while in others only those in certain areas died.

On examination the stalks were found to be discolored for a space of one to three or four inches above the surface of the ground.

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*N. Y. State Agr. Expt. Sta. Bul. 188.

The light pink spore masses of the fungus were very abundant on this area. It is likely that the disease was in the soil when the plants were set out and that it gained access to the plants through the crown or upper roots, as the root system was also badly diseased.

The fungus grows within the tissues and absorbs the nourishment of the plant. Finally the communication between root and top becomes obstructed by the collapse of cells and the filling up of the passages by the fungus hypha.

The only remedy that can be suggested for this disease, since the fungus lives in the ground, is to replace the soil in the beds with fresh earth. This would be practicable only with small beds. But it is possible that the soil can be freed of the fungus by taking certain sanitary precautions. Such measures would consist, first, in burning all diseased plants as soon as they are detected, thus preventing further dissemination of spores; second, asters should not be grown for two or three years in beds where the disease has appeared; the fungus will probably be starved out during this time.

CURRANT CANE DISEASE.

(*Nectria cinnabarina*).

Currant bushes in the vicinity of Fort Collins are seriously affected by a fungus which attacks the canes. It is especially severe on neglected bushes in back yards, but the College plantation, which has always been given good care, was so badly diseased that it was thought best to destroy it. The fungus was also found in an active condition on gooseberry bushes that stood in adjoining rows.

Yellow foliage and dying canes are characteristics of this disease, which often occur on a bush where a portion of the plant appears healthy. As is common with some other plant diseases, many of the canes die after the fruit becomes of considerable size and both fruit and foliage shrivel and cling to the stems. Badly diseased plants are frequently killed. The reproductive bodies of the fungus occur in great abundance on the dead canes in the form of brick-red masses or tubercles, which are shown natural size in Plate VI., Fig. 2.

* Spraying with fungicides is not likely to prove practical as a preventive of this trouble, as spores may be produced at any time during the season. All that can be done is to remove the entire plant and burn it as soon as any part shows evidence of the disease. If allowed to lie on the ground the affected parts may mature spores and spread the disease to other plants. It has been determined that the fungus lives from year to year within the tissues of the currant plant, and that a plant may be infested for some time without show-

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*Durand, E. J. Cornell Univ. Agri. Expt. Sta. Bul. 125.

ing any evidence of disease. Therefore cuttings should not be taken from a plantation in which this fungus has appeared.

GRAPE ANTHRACNOSE.

(*Sphaceloma ampelinum.* De By.)

During the month of June the grape vines in the College vineyard were found to be seriously diseased with anthracnose as is shown in the illustration in Plate VII. Numerous dark colored pits or depressions occurred on the young canes and on the stems of the leaves and fruit clusters. Many of the spots grew into each other as the disease progressed, thus forming continuous depressions which in some cases nearly girdled the affected parts. The centers of the depressions also took on a whitish color, and finally very minute raised points or pustules appeared, in which the spores are born.

The first effect seen on the leaf blade was in the form of fine, irregular cracks with brown edges. Later in the season the leaves presented a torn and ragged appearance where two or more cracks ran together. Leaves attacked when quite young were severely injured and their surface materially reduced, as shown in the plate.

The characteristic appearance of diseased fruit is well shown in the illustration where one fruit is attacked and a seed exposed through a circular wound. The diseased berries do not decay, but the affected portions become hard and shrivelled.

In Europe, as well as in many portions of the Eastern States, this fungus has proven difficult to combat. When once well established in a vineyard it has usually taken two or three years of most thorough treatment to get it under control. Fortunately, however, the disease does not spread rapidly.

It is recommended that the vines be sprayed thoroughly with Bordeaux mixture, beginning early in the spring at the time when the buds are commencing to swell. This treatment should be followed by four or five others made at intervals of about two weeks.

PEA ROOT DISEASE.

During the season of 1900 Mr. C. H. Potter, assistant in Horticulture, gave considerable attention to a destructive pea disease which made its appearance in the vicinity of Longmont. The trouble was not generally distributed, but was confined to certain fields. In these fields where the disease was most severe a majority of the plants were killed before reaching the surface of the ground. Different fields presented all variations in the amount of injury, from partial to complete failures of the crop.

The disease was not so destructive last season, as only a few

fields showed evidence of its presence. I examined one tract of land that had been sown to peas at the usual time in the spring. Most of the seed failing to grow, the ground was plowed and again sown to peas. At the time of my visit the field had the appearance of fallow land, as only an occasional pea plant was to be seen.

The soil in the vicinity of Longmont is well adapted to pea growing, about 2,500 acres being grown there annually to supply the canning factory, which makes a specialty of this product. The fields in which the disease made its appearance have always produced good crops of other kinds. A good crop of wheat grew the year before on the one that I examined.

My attention was called to this disease first in September of 1900, when I took up the work of this department, but no investigations could be undertaken at that time. During the following winter some soil was secured from an infected field, which was placed in flats in the greenhouse and sown to peas.

The plants grown in this soil were nearly all attacked by fungi on the roots and on the stems below ground. The injury was not severe enough, however, to kill them, and as the vines grew and bent over they were attacked at the point where they came in contact with the earth. These diseased areas were soon overrun by various saprophytic fungi, so it was difficult to tell what was the real cause of the trouble. However, there was a large colored hypha constantly present in the diseased parts and the same hypha was found to be abundant in specimens collected in the field by Mr. Potter the summer before and preserved in formalin.

All attempts to cultivate the fungus artificially failed, since it produced no spores and the diseased areas on the stems were so contaminated with other forms that efforts to secure cultures by other means failed. The distinctive character of the hypha showed that it belonged to a group of fungi commonly known as *Rhizoctonia*, and that it was closely related to if not identical with the disease that is so destructive to potatoes in this State.

The soil was then turned over to Mr. Rolfs to determine whether it was infested with this potato fungus with which he was working. A part of it was placed in pots and planted to potatoes. Eight pots were planted with clean potatoes that had been treated with corrosive sublimate to free them from disease. The soil in another lot of eight pots was sterilized with steam for three days, two hours a day, to kill all plant life that it contained. These pots were planted with clean potatoes treated as above. In the first series all the plants were affected with *Rhizoctonia*. In the second all of the plants, with one exception, were free from the disease. The presence of the fungus in the one pot may easily have been due to carelessness in watering, as it stood by the side of the others that contained the unsterilized soil.

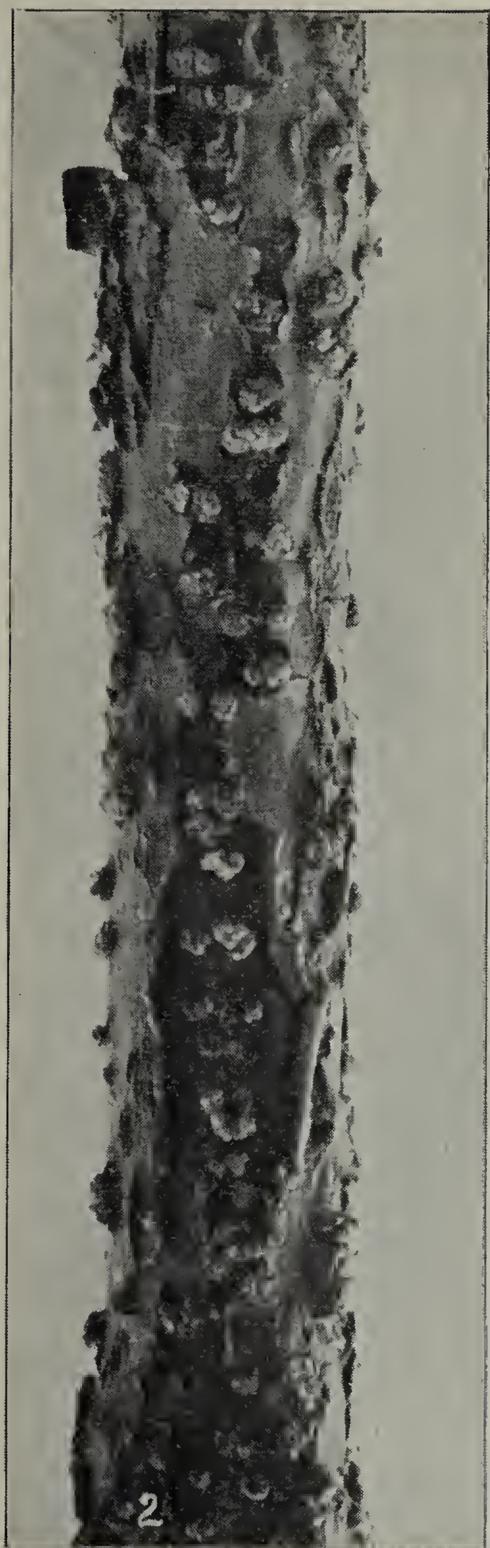
Inoculation experiments were undertaken with potato *Rhizoctonia,* both with pure cultures and with the sclerotia as they occur on potato tubers. Peas were germinated in the laboratory and when the caulicle was about an inch long the inoculation was made. Some of the fungus from the cultures was placed between the caulicle and the cotyledons; then the peas were planted in coarse river sand in the greenhouse. Peas that were not inoculated were planted at the same time to serve as a check on the work. The result of the experiment shows that the fungus occuring on the potato is parasitic on the pea, as the roots of all inoculated plants were badly diseased and in some instances the caulicle of the young plant was cut off. But in no instance were the plants killed, as they threw out new roots above the injury and were able in a measure to overcome the disease. Roots of the pea plants that were injured by the fungus in these inoculation experiments are shown in Plate VI., Fig. 1. The check plants grown under the same conditions, but not inoculated, showed no signs of disease. These experiments were repeated and varied by placing portions of the fungus under both caulicle and plumule. *Rhizoctonia* sclerotia taken from potatoes and started into vigorous growth by placing them in a moist chamber over night were used in the same way; the results were the same as before.

These experiments do not prove conclusively that the so-called *Rhizoctonia* disease of potatoes is the cause of this trouble with peas, but the indications point strongly to this conclusion. It is known that this fungus is destructive to a great variety of plants and these experiments show that it may injure peas. That it did not kill the pea plants in the inoculation experiments may be due to the fact that conditions in the greenhouse were not suitable for the best development of the fungus. The failure of the fungus to kill the peas that were grown in the greenhouse in soil from an infested field must also have been due to unfavorable conditions.

As a result of these observations and experiments it is safe to conclude that the pea disease is due to a fungus that is in the soil when the peas are planted. There is no practical way of detecting its presence until its effects are seen on the pea plants, consequently the discovery of a method of treatment would seem to be a difficult matter; some suggestions, however, obtained from the study of other plant diseases may be of value.

First—The heavier soils should be avoided for pea growing, as root diseases, especially the fungus that attacks potatoes as mentioned above, is much more severe on such soils.

Second—By deep plowing the diseased surface soil may be buried so deeply that the fungus will not come in contact with the young roots. After the pea plants are thoroughly established it is probable that the fungus will have only a slightly injurious effect,



COLORADO
EXPERIMENT
STATION

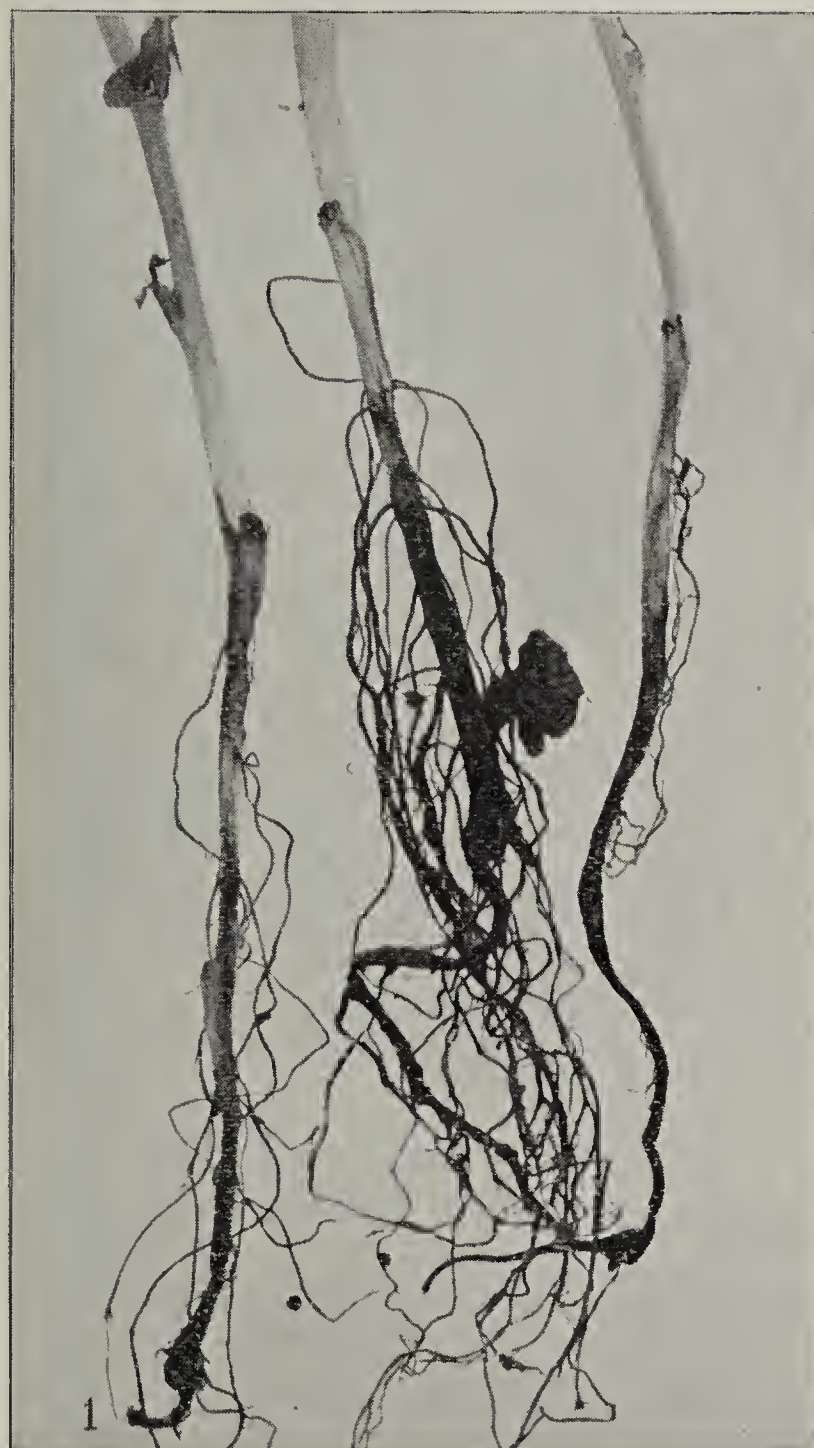


PLATE VI.

Fig. 1. Pea roots injured by inoculating with Rhizoctonia from potato.

Fig. 2. Fruiting bodies of Nectria cinnabarina on currant canes. Both figures natural size.

PLATE VII.

Anthracnose of the grape. Showing injury to cane, leaf, leaf stem, fruit and stem of fruit cluster. Natural size.

as the experiments indicate that the disease is most destructive when the plants are small.

Third—As little water should be used in irrigating as can be gotten along with, since root fungi in general thrive best in a wet soil.

Fourth—It is within the range of possibilities to secure a variety, or strain of some variety, of peas that will resist the attacks of this fungus. Recent reported advances made in plant breeding encourages us to believe that such a strain may be secured, and we hope to undertake work of this nature the coming season.

PLUM LEAF BLIGHT, OR SHOT-HOLE FUNGUS.

A common disease of plum and cherry trees, known as leaf blight or shot-hole fungus, is illustrated in Plate IX., Fig. 1. A common effect of the fungus is to destroy small areas of leaf tissue, which drop out and leave circular holes, thus suggesting the name. When many of these holes run together the greater part of the leaf is destroyed. If the fungus is severe in its attack and the leaf surface is materially reduced during the active growing season great injury is done to the trees.

Numerous experiments have proven that this leaf blight may be easily controlled by spraying with Bordeaux mixture. *Beach recommends that three sprayings be made as follows: The first about ten days after the blossoms have fallen; the second about three weeks after the first, and the third about four weeks after the second.

This disease is reported as being quite abundant in some seasons in sections of Colorado. In such localities it will undoubtedly pay to give the treatment recommended a trial.

POTATO DISEASES.

Potato diseases are being made the subject of special investigation at this Station, as mentioned on another page, and a report of progress of the work is soon to be published in bulletin form. Whether the fungus that has been found to be so destructive to this crop can be entirely overcome has not been determined, but much good can be done by treating seed potatoes.

It is our purpose merely to call attention to the subject at this time, and for the sake of convenience, formulas for disinfecting seed potatoes are given on the following page.

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*Beach, S. A. Rep. N. Y. State Exp. Sta. 1896, p. 399.

An extended discussion of this subject will be found in Bulletin No. 70 of this Station.

FORMULAS FOR TREATING DISEASED SEED POTATOES.

Corrosive sublimate	1 ounce
Water	8 gallons

Dissolve the corrosive sublimate in one gallon of hot water, then dilute with seven gallons of cold water. Allow the potatoes to soak one and one-half hours. When dry they may be cut and planted, though it has been found to be a good practice to treat the potatoes a week or more before planting, since the treatment may retard germination if done just before planting.

Corrosive sublimate is a deadly poison, and it should be used in wooden or earthen vessels, since it corrodes metals.

Formalin	8 ounces
Water	15 gallons

Soak the potatoes two hours in this solution, preferably a short time before planting. This remedy is somewhat more expensive than the corrosive sublimate treatment, but it has the advantage of being non-poisonous, and it may be used in any kind of vessels.

QUINCE RUST.

(*Gymnosporangium.* Sp.)

Last season the quinces in some sections of the Western slope were quite generally attacked by a fungus that is commonly known as rust. The fruits were often much distorted and worthless, as shown in the illustration in Plate VIII., Fig. 1. Any part of the fruits may be attacked, but in this case the blossom end was elongated into a hard knotty mass, on the surface of which was many fine tube-like projections about a quarter of an inch long, in which spores were produced. Fruits which were attacked when quite young were much dwarfed and so distorted that they scarcely resembled quince fruits. The fungus may also attack the stems and leaves of quince trees, but on the few trees that were hastily examined, it was only found upon the fruit.

The peculiar and interesting life history of this plant disease was worked out a number of years ago, which is briefly as follows: The fungus has two stages in its development, which are produced on two distinct classes of plants. The first stage occurs on cedar and juniper trees, on which it produces enlargments of the twigs and branches. The fungus lives year after year within the tissues, and the injuries are gradually extended until the branch or even the tree may be killed. Spores are given off in the spring of the year from conspicuous orange-colored masses which grow out from

the diseased parts. These masses are sometimes mistaken for blossoms or fruit of the tree, and in some sections are known as cedar apples. They are moist and gelatinous in texture during damp weather, so that the first spores readily germinate where they are borne. These in turn give rise to minute secondary spores, which are readily blown about by the wind and which can only grow on some plant that is a member of the family to which the quince belongs. When they chance to fall on a quince tree, and the conditions are suitable for germination, rust is produced. The cedar apples become dry and withered during sunny weather, consequently the dissemination of spores is stopped until another rain softens the mass. Thus it happens that the period of infection may extend over a considerable length of time.

The spores that are borne on the quince trees can only grow when they in turn are carried to the cedars, thus starting new sources of infection.

There are a number of species of this fungus and all of them pass the second stage on some member of the same family of plants. The apple is sometimes attacked, and the service berry that grows in the foot hills and mountains is often badly diseased. Fig. 2, Plate VIII., is from a natural size photograph of a pear that was received from Glenwood Springs, Colo., August 29. A portion of its surface was covered with the spore bearing projections similar to those on the quince. It is an uncommon occurrence, however, for pears to be attacked by this fungus.

Experimenters usually agree that spraying with Bordeaux mixture has little effect in preventing this fungus from attacking fruit trees. They all recommend that the cedar and juniper trees in the vicinity of an orchard be destroyed, which of course is a certain remedy. But since orchard trees have been known to be infected from cedars eight miles away,* this method would not be practicable in Colorado. The quince growing sections of the State are mostly in close proximity to the foot hills and mountains, the sides of which are covered with extensive cedar forests. * Bailey cites an instance in New York, however, where the rust was much less abundant in sprayed portions of an orchard than it was on the unsprayed trees.

There are no records of experiments on the treatment of this disease in the arid regions, but since the dissemination of spores from cedar trees is dependent on the rain fall, it is not probable that the fungus will be so difficult to control as it is in humid climates. For this reason, also, it is not probable that the disease will be so abundant every year as it was last, since it is likely that a rain came at the time which was most favorable for the development and spread of the spores.

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* Bailey, L. H., Cornell Univ. Ag'l. Expt. Sta., Bulletin 80.

However, if it is thought best to try to protect the quince crop, the following line of treatment is recommended: Spray thoroughly with Bordeaux mixture as soon as the fruit has set, and follow this with two or three more sprayings at intervals of ten days or two weeks. The young fruit should be protected with the mixture until the season of late spring and early summer rains is passed.

STRAWBERRY LEAF BLIGHT.

(*Sphærella fragariæ.*)

The illustration in Plate IX., Fig. 2, is from a natural size photograph of a strawberry leaf that was attacked by the common leaf blight or rust. This disease is so common and the characteristic spots which it produces on the leaves are so well shown in the illustration that an extended discussion of the nature and effects of the fungus will not be necessary. It may attack any portion of the plant above ground, and when the leaf surface is materially reduced, small berries are the result. The fruiting stems may be so injured by the fungus that the berries wither before they ripen, and when newly set plants are badly diseased, the future crop may be a failure. Some varieties are much more susceptible to attacks of this fungus than others, and some valuable kinds have to be abandoned in certain localities on this account.

The degree of susceptibility that a variety exhibits toward this disease varies in different localities, but good kinds may be found for every locality which are comparatively free from attacks of rust. Selection of resistant varieties is the most practical method of combating the disease, but it may be controlled by spraying with Bordeaux mixture if it seems desirable to do so. When setting new plants, all diseased foilage should be removed and destroyed, and the plants should be sprayed a few days after setting. The new growth must be protected with the mixture during the fore part of the season. This will require about four sprayings. The next season it is recommended that the plants be sprayed just before they blossom and again as soon as the blooming period is over. If the plants are to be fruited another season, the beds should be mown and burned over as soon as the picking season is passed. If the burning is properly done no harm will result to the plants, and many spores of the fungus will be destroyed.

WHEAT STINKING SMUT.

(*Tilletia fœtens.*)

It is the practice of the wheat growers in many sections of the State to treat their seed wheat with copper sulphate (blue vitriol), for

PLATE VIII.

Fig. 1. Quince attacked by rust fungus.

Fig. 2. Pear attacked by rust fungus.

Fig. 3. Apple injured by spraying with Bordeaux mixtures. All natural size.

PLATE IX.

Fig. 1. Plum leaves injured by shot hole fungus.

Fig. 2. Strawberry leaf attacked by blight. Both natural size.

the prevention of smut. The results of numerous experiments and the experience of many farmers prove that there is no doubt of the efficacy of the treatment. However, occasional failures are reported, some growers claiming that they can see no advantage in the treated over the untreated seed. Such results indicate that the best methods of treatment are not understood by all.

We intend to test the different ways of combating wheat smut in the near future, to determine which one is best suited to our conditions. In the mean time, the latest formulas recommended by the best authorities are given below:

I.

Copper sulphate (blue vitriol)	1 pound
Water	4 gallons

Dissolve the copper sulphate in hot water. Sprinkle or spray the solution on the wheat that has been placed in piles on the floor or on a canvas. Shovel the piles over while the liquid is being applied to insure the thorough wetting of every grain. Use no more of the solution than is necessary and spread out the piles so that the wheat will not remain wet long enough to become heated.

II.

Corrosive sublimate	1 pound
Water	50 gallons

To be applied in the same manner as the solution of copper sulphate.

III.

Formalin	1 pound
Water	50 gallons

Use the same as the other remedies.

Prof. Bolley, of North Dakota, who has experimented extensively with remedies for grain smuts, prefers the formalin treatment to any that he has tried.

FORMULAS.

BORDEAUX MIXTURE.

Copper sulphate	4 pounds
Lime	4 pounds
Water	45 gallons

The copper sulphate must be dissolved in hot water if wanted for immediate use. It may be dissolved by suspending it in a sack in the top of a considerable quantity of cold water, but this method requires a much longer time. If placed in the bottom of the vessel it will not all dissolve. The best quality of stone lime should be purchased, slacked and diluted till it is in the form of a thin white-wash. After the copper sulphate solution has been diluted to about thirty gallons, the whitewash is poured in, stirred thoroughly, and the mass diluted to the required 45 gallons. It is essential that both the copper sulphate solution and the whitewash be quite dilute before they are combined, otherwise a coarse precipitate is formed, which does not pass through the spray nozzles readily.

Where large amounts of Bordeaux are to be used, it is advantageous to keep on hand a stock of dissolved copper sulphate and of slacked lime. The stock of copper sulphate may be made by dissolving, say, fifty pounds in twenty-five gallons of water. Then one gallon of the solution will be equivalent to two pounds of copper sulphate, and two gallons will be required for a barrel of the mixture. The vessel containing the solution should be kept closely covered to prevent evaporation. It should be mentioned, also, that copper sulphate corrodes iron quickly, therefore it must not be allowed to come in contact with iron vessels or tools.

The lime may be slacked in quantities, when it will keep in good condition all summer, if it is not allowed to become dry. A chemical test for copper is taken advantage of to determine the amount of lime paste to be used. This is called the potassium ferrocyanide test. The chemical comes in the form of yellow crystals, and a few cents worth will suffice for the entire season. It should be dissolved in ten times its bulk of water when it is ready for use. A quantity of the lime paste in the form of a thin whitewash is added to the dilute copper sulphate solution, then the mixture is stirred thoroughly. A drop of the test is now allowed to fall on the surface of the mixture. It will instantly turn to a dark, reddish-brown color

if sufficient lime has been used. More lime must be added until the test shows no reaction, when the mixture is ready for use. A slight excess of lime will do no harm and will be a safe-guard against possible error.

Bordeaux mixture deteriorates rapidly, therefore it should be used on the same day it is made.

It is often desirable to apply poison to the same plants that are to be sprayed with Bordeaux. Fortunately the two remedies may be combined and both applied with one operation. Any of the arsenical compounds may be used, and at the same rate when mixed with water.

RESIN-BORDEAUX MIXTURE.

Recommended by * Sirrine for spraying asparagus, cabbage and other plants to which the common Bordeaux mixture does not readily adhere. Also as a poison carrier to make poison mixtures adhere to the same class of plants.

Resin	5 pounds
Potash lye	1 pound
Fish oil	1 pint
Water	5 gallons

Place the oil and resin in a kettle and heat until the ingredients are dissolved. Then remove from the fire, and when slightly cooled, add the lye slowly, while the mass is being continuously stirred. The water is now added and the mixture is boiled until it will mix with cold water, when it forms an amber colored liquid. Care should be taken at all times to keep the materials from boiling over and catching fire.

The above forms a stock mixture of which two gallons are used to forty-eight gallons of Bordeaux made in the usual manner. It is found best, however, to dilute the resin mixture with about eight parts of water before it was added to the Bordeaux.

The materials are used in the same proportions when Paris green or other similar poisons are being used on plants.

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* New York State Agri. Expt. Sta., Bulletins 144 and 188.

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Bulletin 70. **March, 1902.**

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

POTATO FAILURES.

A PRELIMINARY REPORT.

—BY—

F. M. ROLFS.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

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FORT COLLINS, COLORADO.

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Potato Failures.

By F. M. ROLFS.

INTRODUCTION.

The following lines are written to call the attention of the potato growers in this state to a destructive disease of the potato, *Rhizoctonia solani* Kuhn. I am aware of the incompleteness of this report, but it is hoped that a publication at this time may stimulate an interest in the subject and thus call forth suggestions which will be helpful in working out a practical method of overcoming this disease. Undoubtedly this fungus has been common to the potato fields of America for years, and although of considerable economic importance it has been entirely overlooked by American investigators, and nothing of importance concerning its nature has been recorded. *Stewart and Duggar in 1900 published the first account of its occurrence in America.

European investigators have given it considerable attention and European literature contains a number of publications on a potato disease caused by *Rhizoctonia.* Its host plants cover a wide range and a number of species of the fungus have been described.

OCCURRENCE OF DISEASE.

The stem rot of the potato plant was first brought to my attention during the summer of 1900, while at the New York State Branch Experiment Station on Long Island. The potato growers in the various sections of the Island, complained of the early wilting or drying of the vines caused by a stem rot. On visiting these sections and making careful observations it was noticed that the disease in many instances resembled the stem rot of carnations, which is caused by the attack of a species of *Rhizoctonia.*

A microscopic examination of plants that had been recently killed invariably revealed an abundance of this fungus on the stems and roots. At least thirty plantations in various sections of the Island were visited and a number of dead plants from each field were carefully examined. Although other fungi were more or less plentiful on these stems, *Rhizoctonia* was constantly present both in the pith and on the outside of the roots and stems. These observations pointed toward the conclusion that this fungus had

* Bulletins 186 of the New York State Agricultural Experiment Station, and Cornell Experiment Station.

more or less influence on the death of the plants. The stems which had been dead for sometime were so completely overrun by other fungi that it was often difficult to identify the *Rhizoctonia* hyphae.

This Department has received many inquiries from potato growers in various sections of this State in regard to failures of the potato crop. Many of these inquiries gave a description of a diseased condition which is strikingly similar to the one that was so common on Long Island in 1900. After examining the tubers and stems from various parts of the state, it is quite evident that the fungus is common to nearly every section of this state, and especially abundant in many parts where failures occur. This information and the previous observations led us to believe that it is a parasite on the potato plant and that it probably had some influence on the failures recorded in these various sections. Accordingly the writer was detailed to take up this work and the results of the investigations and experiments are given in the following pages.

Our experiments prove that *Rhizoctonia* is an active parasite on the potato plant. Species of this fungus or possibly the same species occur on a great variety of plants among which may be mentioned the following: Beets, carrots, alfalfa, red clover, onions, turnips, peas, celery, lettuce, beans, cabbage, blackberries and raspberries. Usually it is a parasite but it is capable also of existing on dead organic matter in the soil and when favorable opportunities occur it invades and destroys the living tissues of plants.

The annual loss to the State from this disease is considerable. In many localities where potato growing was once a paying industry the soil has become so infected with the fungus that the crop is no longer profitable. Although it is more or less common to many fields, it apparently develops most rapidly in heavy soils which are poorly drained. The disease remains in the soil and grows worse with each succeeding crop, consequently failures are most apt to occur where a systematic rotation of crops is not followed.

Probably every state in the Union suffers more or less injury to its potato crop from this disease. It is known to be common to the fields of New York, Ohio, Iowa, Minnesota, Wisconsin, Florida, Oklahoma, Texas, Colorado, California and Washington.

EFFECTS OF THE DISEASE ON POTATO PLANTS.

In many sections of the State where potatoes are not successfully grown it is reported that large vines are pro-

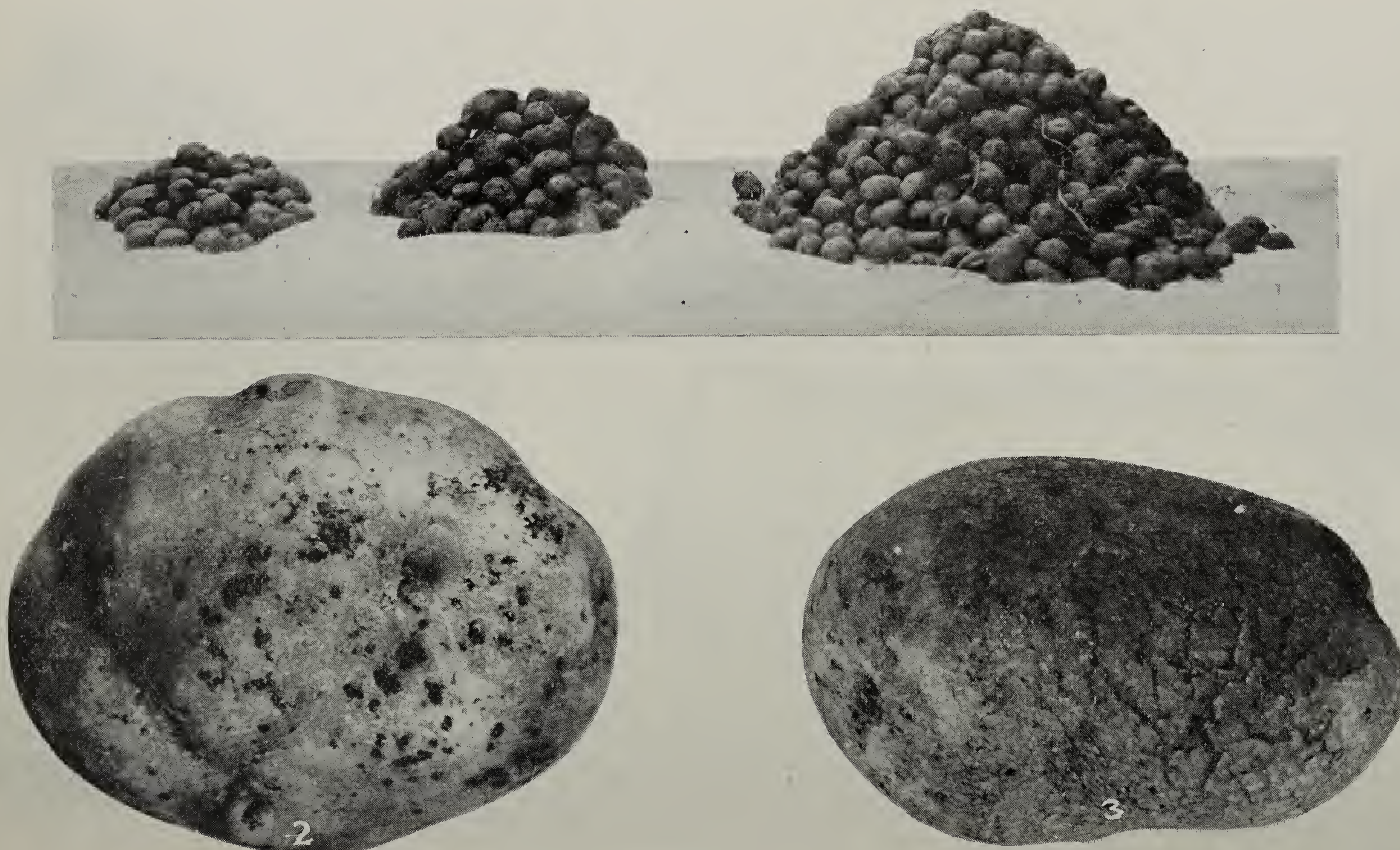

PLATE I.

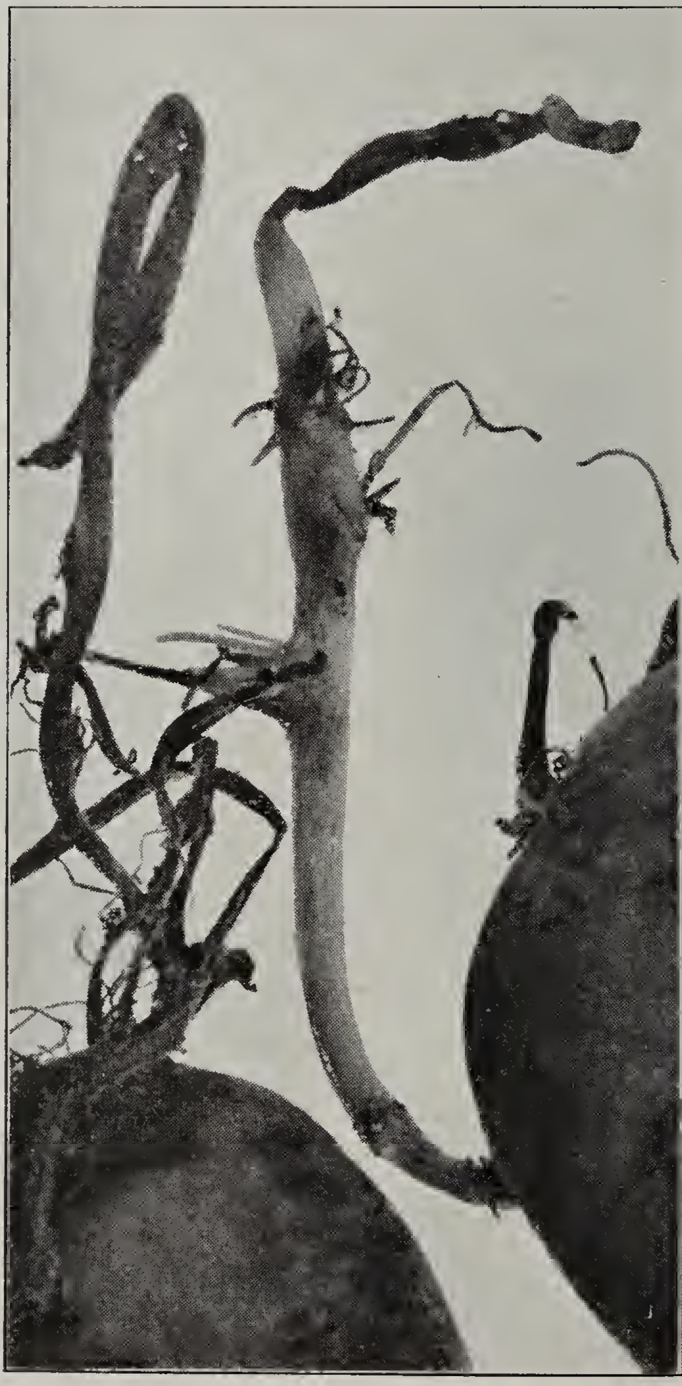

Figure 2.

PLATE II.

duced which give promise of an abundant yield, but when digging time comes it is found that so few tubers have set that it does not pay to dig them. Many of the thriftiest vines fail to produce a single tuber. (See Plate V.) It is a less frequent, but by no means uncommon occurrence, for the vines to set an abnormal number of small potatoes, or "Little Potatoes" as they are sometimes called. These often occur in compact clusters and are so small as to be worthless. (See Plate IX.) The above conditions occur most frequently on poorly drained land and especially on the heavier soils. A third condition and one which is common to the best potato districts is the dying of potato plants thus resulting in poor stands. Our experiments prove that any of these conditions may be produced by attacks of *Rhizoctonia*, and in the vicinity of Fort Collins, where most of our experiments and field work were done, this fungus is frequently responsible for the lack of success in the growing of this crop. So far as we have been able to learn, one or more of these conditions prevail in many sections where the potato crop is a failure.

The question naturally arises why this fungus should be so severe in its attacks on the potato at Fort Collins while the crop is so successfully grown in the Greeley district, twenty miles east and nearly the same altitude. Many farmers claim that if they had Greeley soil they could grow potatoes as successfully as those in the favored section. Our observations go to show that the difference between success and failure in potato growing is principally a difference in soils, not that the successful growers suffer no loss from the attacks of this fungus but that it finds less congenial surroundings in the lighter and better drained land.

NATURE OF THE FUNGUS AND ITS METHODS OF ATTACK.

The hyphae or root-like organs of the fungus are often found growing on the surface and in the scab ulcers of potatoes. These hyphae give rise to irregularly shaped dark masses know as sclerotia, which vary in size from that of a mere speck to areas one-half inch or more in diameter. (See Plate I. Fig 2.) The sclerotia resemble small bits of earth so closely that it is often difficult to distinguish them from particles of soil on the tubers, but by placing the potatoes in water these bodies become black and quite conspicuous. Many of them adhere very firmly. When such potatoes are used for seed the disease is planted with them and it is ready to begin its attack as soon as the new plants start to develop.

This disease like many other root fungi is greatly influenced in its growth by soil conditions. It may occur abundantly in the soil and on the seed potatoes and yet if the conditions are not favorable the plants may escape serious injury. On the other hand, a few diseased seed may cause considerable damage. The hyphae spread through the soil in various directions, hence a single diseased potato plant may be the means of infecting an area of considerable size, since the disease remains in the soil for a number of years.

Young plants are often severely injured by this fungus as shown in Plate III. Here two young shoots were killed before reaching the surface of the ground and the others were severely injured. Such wounds are usually characterized by a reddish-brown color and vary in size and shape.

Infected plants frequently show no marked signs of injury when first dug, but by leaving such plants in the collecting can over night the diseased parts take on a brown color and become quite conspicuous. Experience also shows that microscopical examination often fails to reveal the presence of the fungus if affected plants are not properly cared for after they are dug: therefore it is necessary to keep the plants in a fresh condition if they are to be successfully studied in the laboratory.

If the fungus produces wounds on the young plant that are small and confined to the outer tissues, the plant usually lives but it is apt to suffer more or less injury from the disease later in the season. The appearance of affected plants is familiar to many but the injury is usually attributed to such causes as altitude, dry weather, heat, over-watering, insect attack, blight and frost. Since conditions have a marked influence on the development of the disease there is some variation in the appearance of affected plants. Usually, however, there is no difficulty in its identification. Plants which are attacked while young, if not killed outright, are often dwarfed, take on an unhealthy appearance and frequently die long before the close of the season. On examining such plants one usually finds that the parts below ground are thoroughly infected with *Rhizoctonia* and often the pith of the stem is filled with this fungus. Such infections apparently start from diseased seed potatoes and the fungus grows up the stem, gradually killing the root system and finally starving the plant. (See plate VII.)

In some cases, the disease attacks the plant just below the surface of the ground, and if conditions are favorable for the development of the fungus, it produces a stem rot

PLATE III.

PLATE IV.

which is known in some sections as "Collar Rot" or "Black Ring" of the potato plant. Badly affected plants wilt suddenly and are soon dead and dry. Frequently, however, the attacks on the stem are not so severe but the wounds are so situated as to prevent the free transportation of plant food to the tuber stems, thus cutting off the food supply to the growing potatoes, which consequently remain small. If the injuries prevent the assimilated food from being stored in the subterranean parts of the plant, large tops are produced, and green tubers often form in the axils of the leaves, thus giving rise to the so-called "Aerial Potatoes". (See Plate VIII.) When the root system of such plants is more or less injured, the leaves usually take on a lighter color and have a tendency to fold. The stems become thicker, and grow prostrate, giving the plants a bushy appearance.

A similar condition is brought about by the attacks of the fungus on the tuber-stems. Young tubers are frequently cut off by the fungus as shown in Plate XI. Fig 2. The yield is often materially reduced in this way and it is not uncommon for all of the tubers to be cut off as shown in Plate VI.

When the tuber stems are less severely injured, but the wounds are severe enough to interfere with the flow of plant food to the young potatoes, the buds on these stems just above the wound often develop tubers. But the fungus may continue its work and again injure or cut off the stem above the newly formed tubers. When the main stem is infected with the disease, the tuber-stems are apt to be cut off before they have made much growth. In such cases blind or adventitious buds may push out and form on the main stem around the injured member and develop short-stemmed or stemless tubers as shown in Plate IX. where a typical cluster of "Little Potatoes" have formed. If the root system is also invaded by the disease, the vitality of the plant is reduced and it puts out few or no subterranean stems. The tuber-stems which do grow are probably weak and soon cut off by the fungus. Such plants set few or no tubers and usually take on the peculiar top development described above.

INOCULATION EXPERIMENTS.

The following series of inoculation experiments was undertaken with cultures of *Rhizoctonia* to prove that the disease is parasitic and that its attack on the potato plant may produce the conditions described above. Pure cultures were readily obtained from the sclerotia on tubers. Conditions have a marked influence in the growth of this fungus in the

laboratory as well as in the field; dryness and exposure to sunlight are especially liable to check its development. Test-tube cultures are very sensitive, hence results from inoculations are apt to be misleading, since the culture material may be weak or dead when the inoculations are made, or the conditions under which the plants are growing may be unfavorable for the best development of the fungus.

These experiments were conducted in the field with the exception of No. 2. *Check plants were used in the experiments and all of them remained in a healthy and vigorous condition.

No. 1. On August 24 placed pure cultures of this fungus on twenty tuber stems and carefully covered the inoculations with grafting wax. In this experiment long young stems were selected in order to be able to make the inoculations some distance from the main stem. On August 29 eight of these stems were examined. All of them had brown-colored areas on inoculated surfaces. September 10 examined the remaining twelve stems. Seven had deep scars under the wax and five of these seven developed new tubers above the wound. The remaining five inoculations gave no marked results.

No. 2. July 7 inoculated twenty green stems on plants growing in pots in the greenhouse. Small incisions were made and particles of the culture material inserted. Check wounds were made in the same manner but not inoculated and all wounds were covered with grafting wax. August 21 three of the inoculated stems were found to be cut in two, eleven were deeply scarred and six remained uninjured. Plate XII. shows four stems taken from this lot.

No. 3. Twenty inoculations made September 18 in the same manner as No. 1. Six of the inoculated tuber-stems were killed and the plants produced stemless tubers. Out of six root-inoculations four were killed and two remained healthy. Two of the eight inoculated branches were injured and six remained sound.

No. 4. August 31, inoculated seven stems just below the surface of the ground. The operation was performed as in No. 1. These inoculations were examined September 12. Three produced a distinct black ring around the stems and four gave no marked results.

No. 5. On the same day, August 31, fifteen tuber-stems and five roots were treated in the same way as in No. 1. These inoculations were made close to the main stem. September 12 five stems and the five roots were examined. All inoculations produced brown-colored areas on the inoculated surfaces. September 22 the remaining ten of these inoculations were carefully examined; seven of these had developed deep black wounds under the wax. The remaining three were completely cut off and small stemless tubers had developed on the main stem around the injured tuber stem. More or less of *Rhizoctonia* hyphae were found in all of the wounds.

No. 6. On August 15th twelve green stems were slightly injured with a sterilized knife, and pure culture of the fungus was placed in the wounds and the inoculations were covered with wax. A careful examination of these stems was made on September 6. Three of them were killed. (See Plate XI. Fig. 1.) Six developed marked wounds and three were healthy. Hyphae of the fungus were more or less plentiful in all of the wounds. The five check injuries healed and the stems remained vigorous.

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* In any inoculation experiment it is necessary that uninoculated plants be grown under the same conditions for the sake of comparison. In the following discussion such plants are designated as checks.

PLATE V.

PLATE VI.

7. On August 1st, pure culture of the fungus was placed on five tuber-stems and the cultures were covered with wax. These stems were examined on August 15th, and it was found that the fungus had produced marked wounds on all of them. Two of these stems which were practically cut off are shown in Plate XI. Fig 2. Two of the five stems used for a check were slightly colored under the wax but no traces of the disease were found.

These experiments show that the attacks of the fungus may produce the abnormal development of the potato plant, so common to many of our fields.

It is evident if fungus injuries are responsible for such peculiar development of the plant that mechanical injuries ought to produce similar results. Accordingly a series of experiments was planned tc test these points.

Mechanical Injuries. On August 24th, all of the tubers were removed from forty plants. September 2d, the tubers which had formed during this time were removed and many of the roots were injured. All the plants soon took on the peculiar development described above and 29 of them developed " Aerial Potatoes." These plants were dug September 20 and it was found that many of them had produced typical "Little Potatoes." (See Plate X.) Examinations failed to reveal the presence of *Rhizoctonia* on any of these plants. Check plants growing by the side of those used in the experiment produced normal tops and tubers.

On the same day, a ring of outer tissue about one half-inch wide was removed from around the main stem of twenty-five plants. These plants also took on the peculiar top development and all produced aerial tubers. Plate IX. shows a fair specimen of this lot of plants. Twisting the stem and wrapping a wire firmly around the stem gave similar results.

THE SEED.

During the past spring, the Department made a number of observations on the percentage of infected *Rhizoctonia* tubers in different lots of potatoes offered for sale as seed. One lot examined contained 805 tubers. Ninety-one per cent of these were infected with the disease and were more or less covered with sclerotia. While the remaining nine per cent were free from the sclerotia, careful examination with the microscope revealed the fact that the eyes of most of these tubers harbored a few strands of the fungus. Five of the supposed clean potatoes were placed in a moist chamber and at the end of two weeks, there was an abundance of this fungus on three of them. The other two were completely overrun with *Fusarium* and no traces of *Rhizoctonia* could be found. The

amounts respectively of clean and diseased potatoes in this sack are shown graphically in Plate I. Fig 1.

From another lot of potatoes which had been in sacks for some time 549 pounds were carefully examined. Fifteen per cent were free from disease, so far as could be determined, and 85 per cent were infected. Many of the sprouts had been overrun with the hyphae, and sclerotia had been developed freely on both sprouts and tubers. (See Plate IV.) Some of the sprouts had been completely cut off; the tips frequently suffered most severely, and the ends of many of the sprouts were dead and dry. (See Plate II. Fig. 2.)

Fifteen of the diseased tubers were placed in moist chambers. Five of them developed sclerotia on tubers and sprouts. The fungus on the remaining ten was apparently dead, and no further development took place. These potatoes were carefully watched and examined from time to time. Apparently the development of the disease ceased soon after they had been removed from the sack. Exposure to the dry air and sunlight probably killed the fungus. Experiments and observations indicate that excessive drying and sunlight kills the hyphae and sclerotia which grow on the surface of potatoes, and that the hyphae which grow in the deeper wounds are probably not much influenced by such treatment.

Potatoes from these lots early in the season gave a much lower percentage of infection. In neither case did it exceed thirty per cent. In the lots examined during the winter before the tubers were placed in sacks, the proportion was usually low, and seldom exceeded twenty per cent.

It is evident that under favorable conditions infected potatoes develop hyphae and sclerotia freely after being stored. A few diseased potatoes in a bin or sack of clean ones, under suitable conditions will spread the disease, and in a short time may render the entire lot worthless for seed.

The cracked skin and rough surface on so many potatoes from diseased fields, led us to suspect that *Rhizoctonia* had more or less influence in bringing about this condition and the constant association of this fungus with these injuries also pointed strongly toward this conclusion.

Observations show that the hyphae frequently enter the lenticells of the tubers and produce corroded spots, or minute open pustules. In rapidly growing tubers such openings are often extended, producing numerous cracks which frequently become confluent. These cracks are repaired by a natural effort frequently producing a peculiar corky, or apparently a double skin on the potato as shown in Plate I. Fig 3.

PLATE VII.

PLATE VIII.

And if the fungus continues its attacks, or if other fungi invade the injured parts, repeated efforts are made to repair the damage, and the surface of the potato may be brought into a rough or cracked condition, giving it an unsightly appearance. An extreme case of such injuries is shown in Plate II. Fig 1. That *Rhizoctonia* is the cause of this condition is proven by the following simple experiment.

On September 11, 1901, small amounts hyphae from pure cultures of the fungus were placed on the surface of eighteen small growing potatoes and covered with sterilized grafting wax. On September 25th, two of these potatoes were examined and a number of brown spots were observed on the inoculated surfaces. By a careful microscopic examination it was found that the hyphae had entered the lenticells and produced a small rupture in the skin. On September 26th, a third inoculated tuber was examined and a number of cracks each starting from a lenticell were observed. On October 10th, the remaining fifteen tubers were examined and it was found that ten of these had developed sclerotia abundantly, and the entire covered surface was a net-work of cracks. Two of the remaining five had each a deep crack extending across the tuber. All inoculations produced brown rough surfaces. An abundance of the fungus was found on each tuber, while the five checks which had been treated in the same way with the exception of adding *Rhizoctonia* culture, remained free from cracks.

METHODS OF TREATMENT.

It is difficult to treat this disease, since the external characters usually do not appear until the tissues of the plant are thoroughly invaded with the fungus. Applications of fungicides to affected plants would have little or no influence on the disease. Under favorable conditions the fungus spreads rapidly through the soil in various directions. There is no practical method of checking its spread after it is once introduced into the soil. The only way of dealing with it is by preventive means. From the nature of this fungus, it is evident that diseased seed potatoes are frequently the means of introducing the disease into clean fields; hence, too much care cannot be exercised in selecting clean seed. But even then, the potatoes are apt to harbor the fungus if they have been in contact with infected tubers. Danger from this source may be largely overcome by the treatment given on page 12.

The disease may be carried on beet roots, or dead potato stems or on the dead stems of many of the weeds which grow in the potato fields. Infected potato and weed stems often find their way into the barn-yard and compost heap, thus manure may become a source of general infection to clean fields. Great care should be taken to keep diseased plants and tubers out of the manure. The burning of all vines and weeds, as soon as the potatoes are harvested, is an excellent practice.

Some fields seem to be more favorable for the development of this fungus than others. A heavy poorly drained field seems to be of the favoring class. A thorough drainage of the land would probably do much good. Potatoes grown on heavy soils with good bottom drainage usually suffer less severely from the disease than those grown on poorly drained soils. It is not definitely known how long this disease will remain in a field when it once becomes thoroughly established, but it is quite evident that land on which diseased potatoes have been grown usually harbors the fungus a number of years, hence, it is important to follow a systematic rotation of crops, and it will probably be necessary to follow a five-year rotation in order to obtain good results.

"Prunet* believes that the fungus remains in the soil three years, and recommends that diseased fields should not be cropped with lucern or clover for several years. Evidences indicate that root crops should be avoided. Cereals which are probably not attacked by *Rhizoctonia* should be sown in the infected ground, and all weeds should be kept down. This is probably the only means by which the fungus can be destroyed."

Corrosive Sublimate Treatment. Corrosive sublimate or bichloride of mercury is sold in form of white crystals. It may be bought at any drug store for about fifteen cents an ounce. The cost of material for treating the seed for an acre will not exceed fifty cents. The solution is made by placing one ounce of this chemical in an earthen or wooden dish containing one gallon of hot water. As soon as it is all dissolved pour the contents of the dish into a wooden vessel containing seven gallons of water. Put the potatoes into this solution, and let them remain an hour and a half. The solution may be used a number of times. The disinfection may be done at any time. Experiments indicate, however, that treating the tubers about a week before planting, and spreading them on the floor or ground where they will be fully exposed to the sunlight, greatly facilitates their growth after planting. *Corrosive sublimate is a deadly poison to both man and animal when taken internally*, but the solution and treated potatoes may be handled freely without experiencing any ill results.

FORMULA.

Corrosive Sublimate	1 ounce
Water	8 gallons.
Soak Potatoes	1½ hours.

*(Prunet "Sur le *Rhizoctonia* de la Lucerne". Compt. rend. Paris 1893.

PLATE IX.

PLATE X.

Formalin Treatment. Formalin is sold in the form of a liquid at about fifty cents a pint. It is a little more expensive than corrosive sublimate but has the advantage of not being poisonous, comes in form of a liquid, and can be used in any kind of a vessel. The solution is made by adding one half-pint of formalin to fifteen gallons of water. The tubers are placed in this solution for two hours. This treatment does not retard the sprouting of the tubers, and it may be used at any convenient time before planting. If the tubers are treated during the winter, they should be dried and carefully stored avoiding all danger of reinfection from infected sacks and bins. The solution loses strength on standing, and must be kept in a closed receptacle if it is to be used a number of times. It is probably not best to use the solution for more than four successive treatments.

FORMULA.

Formalin	8 ounces (½ pint.)
Water	15 gallons.
Soak Potatoes	2 hours.

Keeping Seed Potatoes. It is evident that the success of the potato crop depends much upon the vigor and condition of the seed potatoes. Some growers have adopted the following practice with excellent results: When the potatoes are dug, those which are to be used for seed are stored in a dry, dark shed or barn until about the 10th of November. Just before freezing weather sets in, the potatoes are carefully sorted, and those which show the slightest signs of decay are rejected. A layer of straw from eight to ten inches thick is spread on the ground and the tubers placed upon this straw. The piles should not be made too large. The best results are usually obtained from mounds three feet wide at the base and piled up in ridges as high as convenient. A covering of straw is placed over the potatoes, and this is followed by a layer of soil from six to eight inches thick, but before severe weather sets in more soil is added, and when the severest weather is at hand, more straw, or strawy barn manure is added. The aim is to cover gradually as the cold increases. This method of storing potatoes seems to winter them much better for seed than when they are placed in root cellars, or when they are stored in mounds immediately after they are dug. About the last of April they are taken from the pit and again stored in a dark shed or barn until about ten days before planting-time when they are treated with corrosive sublimate, as given in formula on page 12. After this treatment they are placed where they will be freely exposed to the sun. Seed should not be cut until shortly before planting. If

planting is delayed, the cut pieces should be placed in a moist, cool place.

EXPERIMENTS IN TREATING SEED POTATOES.

Greenhouse Experiments. The following experiments were conducted in the greenhouse to get some hints on the value of treating infected tubers with corrosive sublimate:

Experiment I. The first experiment was with sixteen pots filled with sandy, clayey soil which was thoroughly infected with the disease. The soil in eight of these pots was sterilized two hours a day for three consecutive days, and planted with apparently healthy seed which had been placed in a solution of one ounce of corrosive sublimate to eight gallons of water for one and one-half hours. All tubers produced healthy and quite vigorous plants which lived until the experiment was closed. Careful examinations showed that all but one of these plants were free from disease. This infection was probably due to carelessness in watering the plants with a hose, since pots containing treated and untreated soils stood side by side. The soil in the other eight pots was not sterilized, and planted with clean tubers, treated in the same manner as those in the first lot. The potatoes all grew, but the plants did not do so well as those in the first lot, and three of them died shortly before the experiment was closed. On examination, it was found that all the plants were infected with the disease. A number of sclerotia were found on four of the tubers.

Experiment II. The second experiment contained twelve pots of heavy black loam which had been used in growing Alternanthera in the greenhouse during the preceding winter. The soil in the first four pots was not sterilized and was planted with tubers on which there were numerous sclerotia. These tubers were treated with one ounce of corrosive sublimate to eight gallons of water for one and one-half hours. The plants did quite well, but careful examination showed that all were more or less affected with the disease. The soil in the next four pots was sterilized two hours a day for three consecutive days, and planted with seed treated in the same way as those in the preceding lot. These plants made good growth and lived until the experiment closed. Critical examination failed to reveal any traces of the disease. The soil in the last four pots was treated as in the second lot, but was planted with infected tubers. One tuber failed to grow. Two produced weak plants which died prematurely and the fourth plant did poorly, but lived until the experiment closed. All plants were infected with *Rhizoctonia*.

Experiment III. In the third experiment, thirty diseased tubers were planted in a bench containing three inches of potting sand on the bottom and four inches of sandy clay loam on top. The first lot contained fifteen tubers which were treated with one ounce of corrosive sublimate to eight gallons of water for one and one-half hours, and planted twelve inches apart. These plants were slow in reaching the surface of the ground, but otherwise, they did nicely, and remained green until the close of the experiment. Thirteen of these hills, containing fifty-seven plants, were free from the disease, and only one plant in each of the other two hills, containing eight plants, was infected. It is possible that this was due to soil infection. In the second lot used in this experiment, the tubers were not treated, otherwise the conditions were much the same as in the preceding. Some of the plants soon reached the surface of the ground; others, however, were considerably delayed, and a number were killed before reaching the surface. Those which finally became established did quite well apparently, but twelve of the hills, sixty plants, died two weeks before the experiment was closed, and all were covered with an abundance of *Rhizoctonia* hyphae. The other three hills, fifteen plants, lived, but a careful examination showed that all of them were more or less affected with the disease.

These experiments show that diseased potatoes may be readily disinfected with the corrosive sublimate. But in or-

der to obtain good results the treated seed must be planted in soil which is free from the disease.

Field Experiments. Encouraged by the promising results in the greenhouse experiments, although somewhat late in the season, we concluded to try the treatment on a larger scale. Accordingly arrangements were made with Mr. J. G. Coy of Fort Collins, to carry on an experiment on his farm, in which he kindly consented to assist us. The soil of the field selected for the experiment was of heavy black loam on the river bottom. It was afterwards found that the level of the soil water was comparatively close to the surface. It had been flooded by late rains, and was too wet to get in shape for planting before June 6th. Most of the ground had been planted alternately with cabbage and onions during the past five years. It is quite probable that the soil contained more or less of the fungus since onions which remained in the field from last year's crop were badly infected. Potatoes grown on this place have suffered more or less from early blight for a number of years.

This field was divided into four plots. The rows were twelve rods long and planted in the usual way. All four plots were planted with Wisconsin seed of the Pearl variety. These tubers were infested with *Rhizoctonia.* Plots I., III. and IV. were sprayed with Bordeaux mixture, and Paris green on July 7th, 17th, 31st and August 15th. The seed of Plots III. and IV. was treated with corrosive sublimate as given on page 12. The seed of Plots I. and II. was not treated. The rains during the fore part of the season kept the ground sufficiently moist for the growth of the plants and the field received its first irrigation on August 13th. From this time on the ground was kept quite moist. The potatoes were dug October 10th.

Plot I. This plot occupied the lowest and most poorly drained part of the field. The seed of this lot was not treated, but the plants came up nicely, and most of them looked promising during the early part of the season. They were sprayed thoroughly four times, and remained green until killed by frost. Joining this plot was a garden patch of potatoes which was badly infected with the *Rhizoctonia.* The leaves of these diseased plants soon took on a lighter green color, had a tendency to fold, the stems became heavier, their internodes remained short, and in many of the plants, grew prostrate. These tops were soon invaded and completely ruined by early blight. During the later part of July, it was observed that a number of the plants in the rows joining the garden patch were taking on an abnormal top development. After the first watering, this peculiarity became prominent on many other plants, and at the close of the season, it is doubtful if there was a single plant in the entire plot which had a normally developed top. On August 10th, a careful examination was made of fifty plants taken from various parts of this plot, and it was found that the hyphae of *Rhizoctonia* occurred most abundantly on the plants in the first three

rows joining the infected patch. Apparently the disease gradually spread from the infected soil. Most of the plants in this plot developed small tubers and some of them grew no tubers at all. From eight rows one hundred and forty pounds of rough, corky potatoes were gathered. In some cases the plant apparently failed to put out tuber stems, while in others, the stems which were put out had been injured or completely cut off, producing Little Potatoes, and a number of the plants produced Aerial Potatoes. On October 10th, it was impossible to find a plant in the plot which was not more or less affected with the disease. The root system was also abnormally developed. It too showed the effects of the disease. The younger roots and root tips suffered most. Many of them were dead, and a careful examination of the living and recently killed parts showed the presence of an abundance of *Rhizoctonia* hyphae.

Plot II. was used for check. The seed of this plot was not treated, and the plants were not sprayed. They came up nicely, but some of these blighted early and many of them were killed fully two weeks before frost. It was found on examination, that many of these plants were more or less affected with *Rhizoctonia.* Nine rows yielded 1128 pounds of tubers, which averaged 94 pounds per sack.

Plot III. was planted with the roughest and poorest tubers of this lot of seed. They were treated with corrosive sublimate one day before planting but only about three-fourths of the tubers grew, and the plants were unusually slow in reaching the surface of the ground. This plot was sprayed four times. Diseased plants were less plentiful in this plot than in the preceeding. Seven rows produced 910 pounds of tubers, giving a gain of 4 per cent over check. These tubers averaged 102 pounds per sack.

Plot IV. The seed of this lot was treated with corrosive sublimate one day before planting. The plants were fully five days later in reaching the surface of the ground than those of Plot II, but four weeks later there was very little difference in the size of the plants between the two lots. These plants were sprayed four times which kept their foliage in an excellent condition, until injured by frost. Fifteen rows yielded 2,625 pounds of clean, smooth tubers, giving a gain of 40 per cent over check. It is quite evident that this gain would have been considerable more had the frost been a month later. The tubers averaged 106 pounds per sack.

For the sake of comparison, the methods of treatment and the yields of the different plots are given the following table.

TABLE I. RESULTS IN TREATING SEED POTATOES.

Plot.	No. of rows.	Treatment of seed.	No. times sprayed.	Yield per row in lbs.	Gain over plot No. 2.	Average lbs per sack.
No. 1	8	None.	4	$17\frac{1}{2}$	861 loss.	
No. 2	9	None.	None.	$125\frac{1}{3}$	———	94.
No. 3	7	Corrosive sublimate.	4	130	4	102.
No. 4	15	Corrosive sublimate.	4	175	40	106.

The results of these experiments may be briefly explained as follows: The poor yield in experiment No. 1, may be accounted for by the fact that the plot was situated by the side of a badly infected garden, where potatoes had been grown for several years. It is probable that the disease spread through the soil from the infested patch. (The result of this experiment cannot be considered for this reason.)

PLATE XI.

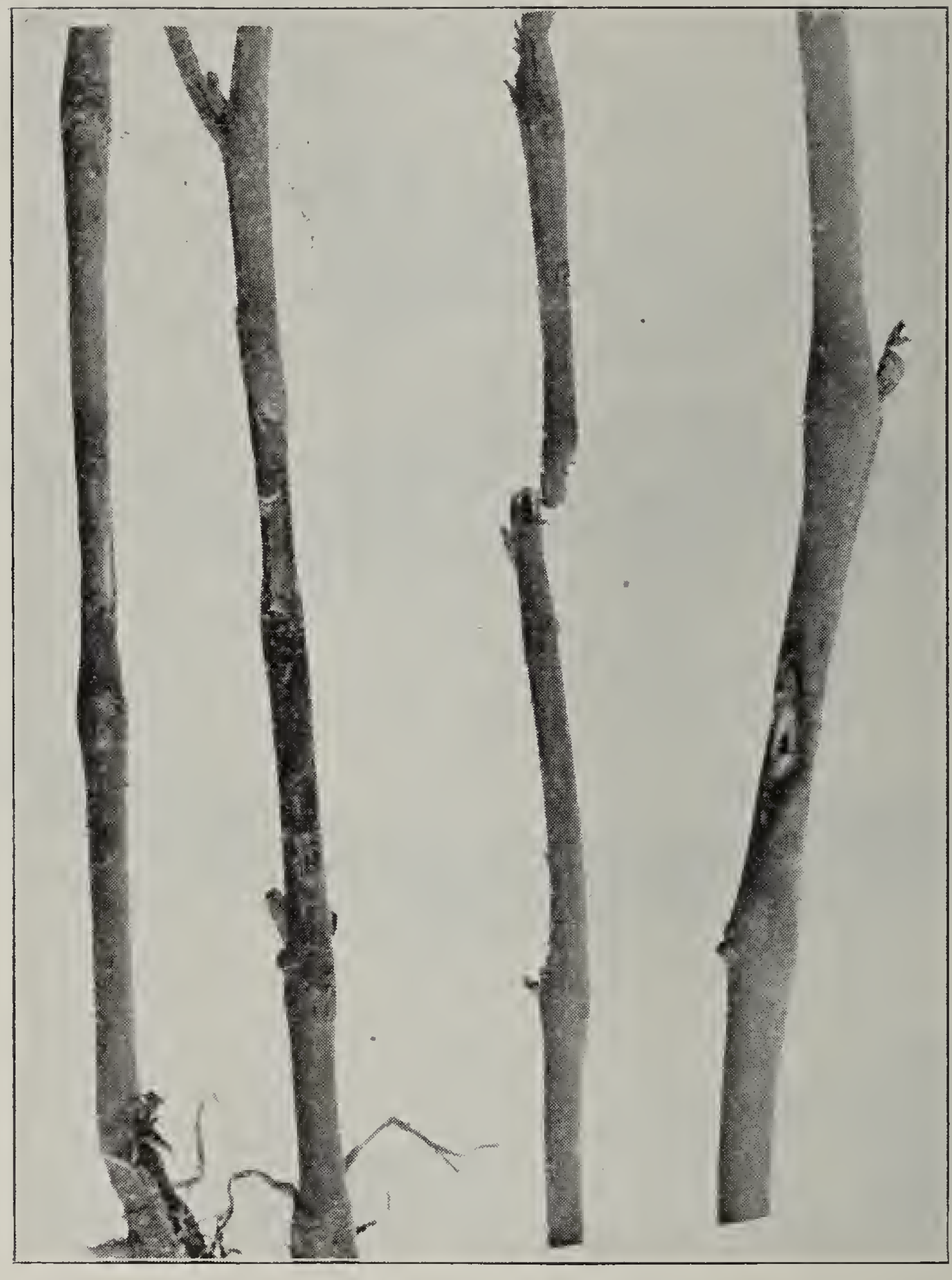

PLATE XII.

In Plot No. III. poor seed was selected which was treated with corrosive sublimate. That only three-fourths of a stand was secured was undoubtedly due to weak seed. The slight gain over the untreated seed indicated that in any method of treatment, it will pay to carefully select the seed potatoes.

The seed potatoes used in Plot No. IV. were of the same quality as those used in Nos. 1 and 2, and were treated with corrosive sublimate. The plants were sprayed four times. The results show a gain of 40 per cent over the untreated seed in Plot No. II.

The difference in the average weight of sacks of potatoes of the same size from different plots is interesting; the potatoes from Plot No. 4 averaging 12 pounds more to the sack than those grown in check Plot No. II. No explanation for this difference is offered at this time.

These experiments show that early blight can be held in check with Bordeaux mixture if the spraying is commenced early, and done thoroughly, but it is probably a waste of time and material to spray plants badly infected with *Rhizoctonia.*

FUTURE INVESTIGATIONS.

Different varieties of potatoes vary considerably in their susceptibility to disease when grown under the same conditions. It has been observed frequently that of plants of different varieties grown in the same hill, and probably equally exposed to infection, some will die early in the season, and produce no tubers at all, while the others will live to the end of the summer and produce a fair yield. Even plants of the same variety often show considerable difference in power of resisting the disease. The cause of such resistance will be studied, and it is hoped that in time a number of hardy or disease resistant varieties may be produced.

The best method of treating and wintering the seed is receiving careful attention, and it is believed that bin and sack infections can be largely prevented.

Some sections seem to have much trouble with the running out of potatoes. The indications are that this condition may be overcome, in some cases at least, but it will be necessary to repeat the experiments another year before making a report.

Field observations indicate that *Rhizoctonia* frequently produces a rot of potato tubers. However, only two tubers out of more than one-hundred inoculated in the laboratory gave marked results, but many were slightly decayed.

These negative results may have been due to unsuitable conditions. A thorough study of this phase of the disease will be made during the coming season.

From a number of observations during the year, it is quite evident that the *Alternaria* which infest the onions of this section may also invade the foliage and produce early blight of potatoes. Hence it was found necessary in the field experiments to spray the plants with Bordeaux mixture as a preventive of this disease. Further observations may show that early blight is an important factor in producing potato failures in some sections. Should this prove to be true it may be controlled with Bordeaux mixture. Onions also frequently harbor *Rhizoctonia*. This probably explains why potatoes so frequently do poorly when planted in onion ground.

Experiments during the past year indicate that sulphur has very little or no value in treating this disease. Lime may prove helpful. Both sulphur and lime will be given a thorough test during the coming season.

Preliminary experiments in rejecting all infected seed potatoes gave excellent results.

ACKNOWLEDGEMENTS.

In conclusion I wish to offer my sincere thanks to Prof. Paddock who has made many helpful suggestions in this work. The illustrations of this bulletin were all taken and arranged by him. I am also indebted to Mr. J. G. Coy of Fort Collins, for his co-operation in the field experiments.

SUMMARY.

Rhizoctonia solani (Kuhn) is the name given to a fungus which occurs on the underground parts of the potato plant. Our experiments show that this fungus is an active parasite on the potato and that it is one of the principal causes of potato failures in many parts of the state.

Many potato growers are familiar with one or more of the following conditions which have usually been thought to be due to the influence of altitude or climate; abnormally large vines which produce few or no potatoes, (See Plate V.) vines which though vigorous in appearance, bear a large number of small, worthless tubers, (See Plates IX. and X.) The failure of much of the seed to grow or the dying of plants during the fore part of the season resulting in a poor stand, (See Plate III.) This fungus, in the vicinity of Fort Collins at least, frequently produces all of these conditions.

The fungus lives over winter on the potatoes in the form of dark patches which resemble bits of soil (See Plate I. Fig 2.) When such potatoes are planted the fungus develops with the plant and begins its attacks at once.

When a field has become thoroughly infected with the disease it will remain in the soil a number of years.

The nature of the disease indicates that it may be combatted by preventive means which consist in planting clean seed in clean soil. Seed potatoes should be carefully sorted, disinfected and planted on land that is well underdrained. Then by practicing a long and systematic rotation of crops, the soil may be prevented from becoming badly infected with the disease.

The fungus may spread from a few diseased potatoes in a sack or bin and in a short time render the entire lot worthless for seed.

In our experiments diseased seed potatoes treated with corrosive sublimate and sprayed with Bordeaux mixture gave an increase in yield of forty per cent over untreated seed and unsprayed plants. The soil used in the experiments was heavy, poorly drained and infected with *Rhizoctonia*. A lighter, well drained soil free from the disease undoubtedly would have given still better results. The formalin treatment also gave encouraging results.

EXPLANATION OF PLATES.

PLATE I. FIG. 1. Sack of potatoes examined June 3. Large pile contains badly diseased potatoes, slightly diseased in the center, while the smallest pile contains the clean potatoes.

FIG. 2. Sclerotia of *Rhizoctonia* on potato. Very common on seed potatoes.

FIG. 3. Surface of potato covered by net work of fine cracks caused by attacks of *Rhizoctonia*. Figs. 2 and 3 natural size.

PLATE II. FIG. 1. Potato badly scarred by *Rhizoctonia*. Much of the so-called scab is undoubtedly due to this disease.

FIG. 2. Potato sprouts killed in the sack by the fungus. From the sack shown in Plate I. Both figures natural size.

PLATE III. Showing how *Rhizoctonia* attacks young plants in the field. Two on the right were killed before reaching the surface of the ground. The others badly injured. Natural size.

PLATE IV. Potato sprouts from sack. Some killed by and others showing sclerotia of *Rhizoctonia*. Enlarged.

PLATE V. Plant from which potatoes were all cut off by *Rhizoctonia*, producing an abnormally large top.

PLATE VI. Large vine from which all but a few small potatoes were cut off by the fungus.

PLATE VII. Potato plant infected from diseased seed; the root system badly injured.

PLATE VIII. Potato plant from which the tuber stems were all cut off by the fungus. As a result a large top was produced and tubers formed in the axils of the leaves.

PLATE IX. "Little Potatoes" and "Aerial Potatoes" produced by ringing the main stem. August 24.

PLATE X. "Little Potatoes" and "Aerial Potatoes" produced by removing all potatoes twice during the season. August 24 and September 2.

PLATE XI. FIG. 1. Three green potato stems inoculated with cultures of *Rhizoctonia*. One completely cut off, the others nearly girdled.

FIG. 2. Two tuber stems inoculated as above. Both cut off by the fungus at the discolored point. All natural size.

PLATE XII. Green stems inoculated with cultures of *Rhizoctonia*. One cut in two, the others badly injured. Natural size.

EXPRESS BOOK PRINT
FORT COLLINS, COLO

Bulletin 71. April, 1902.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

INSECTS AND INSECTICIDES.

—BY—

C. P. GILLETTE.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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INSECTICIDES.

INSECTICIDES. (Preparation and Use).

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1. White Arsenic.
2. Arsenic Bran-mash.
3. Paris Green.
4. Scheele's Green (Green Arsenoid).
5. Arsenate of Lead.
6. Arsenite of Lime.
7. London Purple.
8. Bordeaux Mixture.
9. White Hellebore.
10. Borax.

Substances that Kill by External Contact.
11. Soap.
12. Whale-oil Soap.
13. Fish-oil Soap.
14. Kerosene Emulsion.
15. Kerosene-milk Emulsion.
16. Kerosene and Crude Petroleum.
17. Gasoline.
18. Turpentine.
19. Lye and Washing Soda.
20. Lime.
21. Lime, Salt, and Sulphur Wash.
22. Resin Soap (Summer Wash).
23. Resin Soap (Winter Wash).
24. Pyrethrum or Buhach.
25. Tobacco.
26. Sulfur.
27. Hot Water.
28. Carbon Bisulfide-"Fuma."
29. Hydrocyanic Acid Gas.

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INSECTS AND INSECTICIDES.

C. P. Gillette.

Bulletin 47, treating of "Colorado's Worst Insect Pests and Their Remedies," is out of print. As there is much demand for a bulletin of a general nature treating of the insects that are most injurious in Colorado, and the methods by which they may be destroyed or kept in check, the present publication has been prepared. In the first part of the bulletin, dealing with insects injurious to Colorado fruits, it has been the plan to treat the more common insects only, and to treat each as briefly as possible and still give the necessary information to enable the farmer or horticulturist to decide what insect is doing the injury in a particular case, and what remedies he should use. The object of the second part of the bulletin, treating of the "Preparation and Use of the More Important Insecticides," is well stated in the title. Many substances that are rarely used, and others which are of little or no value, are not mentioned.

The insecticides are numbered in the order in which they are taken up. They are also referred to by number in the first part of the bulletin, which makes it easy to refer to them. When more than one remedy is mentioned, they are given in the order of their preference.

PART I.

INSECTS INJURIOUS TO THE APPLE.

ATTACKING THE FRUIT.

CODLING MOTH.

Flesh-colored larvæ eating into the fruit and causing wormy apples. The first brood of larvæ (worms) begin eating into the fruit when early apples are about an inch in diameter. This brood is not very numerous, but it develops into a second brood about seven weeks later which is very much more numerous. The moth and its eggs are shown at Plate I., Figs. 3 and 4.

Remedies.—The arsenical poisons are, by far, the best remedies we have for this insect. See remedies 4, 3, 6, 8, 7, 5.

The combination of Bordeaux mixture (8) with the arsenites is very popular farther east where fungus diseases are prevalent. The writer believes there is no occasion as yet to use Bordeaux mixture upon apple trees in Colorado except for the purpose of causing the poison to adhere better to the foliage.

Make the first application as soon as the blossoms have faded and nearly all fallen. Continue the application till every calyx (blossom) is filled with the liquid. Repeat the application in one week. If heavy storms follow to wash out the poison, make a third application as soon as the storm is over. Upon the thoroughness of the first and second applications the success will chiefly depend. Just what degree of success may be expected from later applications has not been thoroughly determined. *Professor Cordley, of Oregon, seems to have proven that late spraying is very important in that State.

Bandages (36) are also of considerable service if carefully attended to. Lights to trap the moths are valueless. Screen cellar windows and doors where fruit is kept.

Plate II., Fig. 1, shows blossoms from which the petals have fallen and also small apples with their blossoms (calyces) tightly closed, so that little or no spray could be forced into them, all upon a single spur of a Duchess tree at one time. The blossoms at (a) are in just the right condition to receive and hold the poison. The two apples should have received the spray a full week earlier.

ATTACKING THE FOLIAGE.

LEAF-ROLLERS.

The fruit-tree leaf-roller (*Cacœcia argyrospila*) is a green larva with a black head and measuring about three-fourths of an inch in length when fully grown. The larvæ begin to hatch with the opening of the buds of the apple trees in the spring. They attack at

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*Bull. 69, Or. Exp. Station.

once the tenderest leaves and fold them about themselves for protection. When abundant they may completely defoliate the trees. They disappear during June and do not appear again until the following spring. In the meantime the eggs may be found in little gray patches anywhere upon the bark of trunk or limbs. See Plate I., Fig. 5.

Remedies.—Crush as many as possible of the egg-patches during winter and early spring. The best remedy is to spray thoroughly with one of the arsenites (4, 3, 6, 8, 5) as soon as the first leaves are out. Repeat in one week. Make a third application in another week or ten days if it seems necessary.

Protect the toads and insectiverous birds, as both feed freely upon the rollers. The blackbirds are especially destructive to them.

FALL WEB-WORM. (*Hyphantria cunea.*)

This insect is often mistaken for the next species. The webs are larger and loose or open and the caterpillars stay in them to feed.

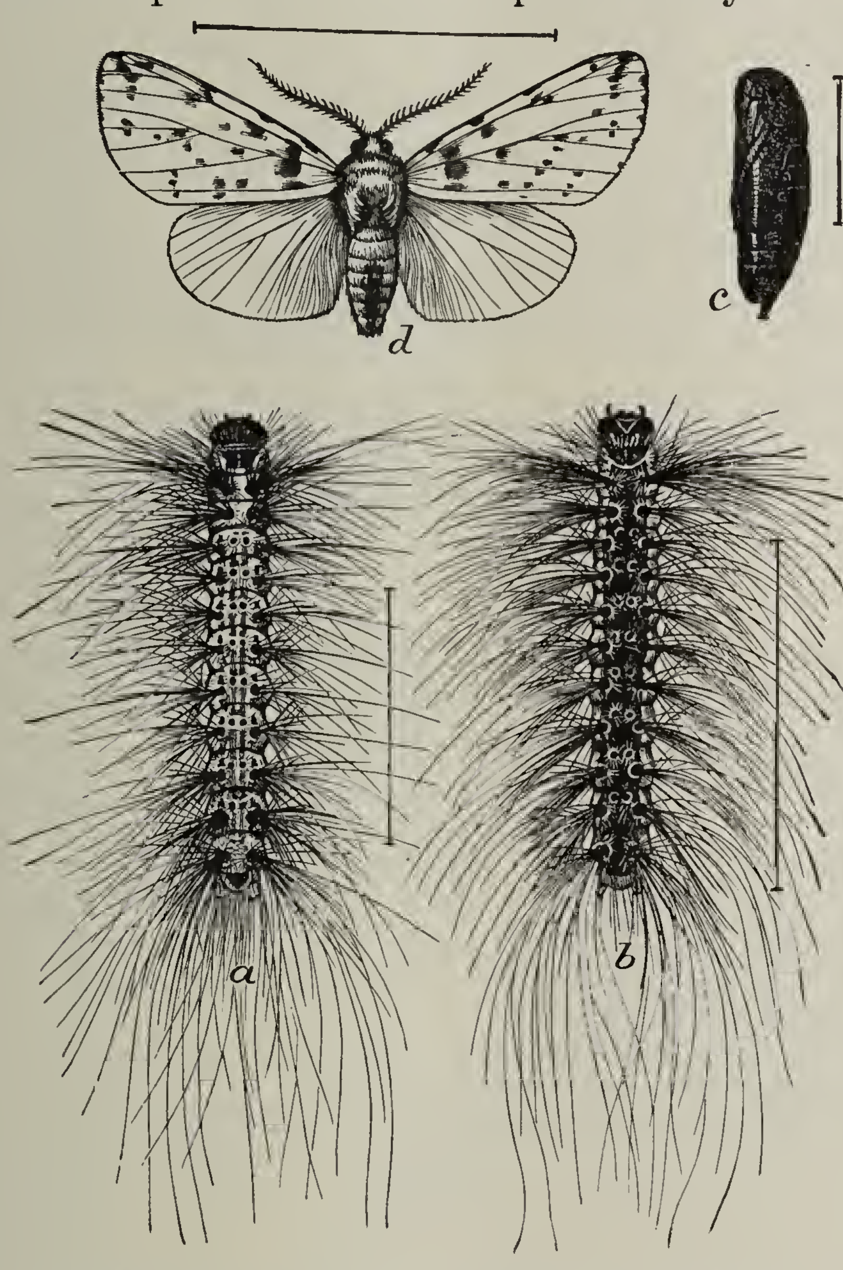

FIG. 1.—Fall Web-worm: *a* and *b*, caterpillars; *c*, chrysalis; *d*, moth. (Howard, Yearbook, U. S. Dep. of Agriculture, 1895.)

When the leaves within the tent are devoured, the web is extended so as to take in more foliage. These tents also appear later in the season than those of the following species. They will seldom be noticed before the middle of July. The adult insect is a white moth, sometimes speckled with black. See Fig. 1.

Remedies.—The same as for the following species except that it is not practical to collect the eggs which are deposited upon the leaves.

TENT CATERPILLAR. (*Clisiocampa fragilis.*)

This insect also hatches as soon as the leaf buds open, and builds small webs in the forks of the branches. A large number of caterpillars inhabit a web or tent, which is increased as necessity requires. See Plate I., Fig. 1.

Remedies.—While the foliage is off, collect the large egg-clusters which are stuck to small limbs. They are covered with a dark, spongy material and are quite readily seen, appearing as galls or swellings of the limbs. If this remedy has been neglected, spray with the arsenical mixtures (4, 3, 6, 8, 5). While the tents are small they may be cut out and burned if on small limbs. If on large limbs they may be burned out with a torch.

APPLE FLEA-BEETLE. (*Haltica* sp.)

The apple flea-beetle is a small metalic-green insect, about an eight of an inch in length, which jumps or drops from the foliage when disturbed. It is most abundant on young trees or nursery stock or sprouts.

Remedies.—Any of the arsenical mixtures (3 to 8) are effectual in destroying this insect or driving it from the foliage. It can usually be driven from the leaves by the application of dry substances, such as lime, ashes, plaster, etc. (32, 33).

BROWN MITE. (*Bryobia pratensis.*)

The brown or clover mite is extremely small and its presence is usually first detected by the faded, sickly appearance of the foliage. See Plate III., Fig. 1. The trees appear to need more water. The mites feed upon the leaves but deposit their rust-colored eggs upon trunk and limbs. When very abundant, these eggs color the bark red, which is most often noticed during winter.

Remedies.—To destroy the eggs while the trees are dormant (during winter), use lime, salt and sulfur mixture (21); kerosene emulsion (14), quadruple strength; whale-oil soap (12), quadruple strength, or crude petroleum (16). To kill the mites during summer use kerosene emulsion or whale-oil soap of ordinary strengths. It is far better to treat the eggs.

APPLE PLANT LOUSE. (*Aphis mali.*)

A green aphis curling the leaves of apple trees, most abundant late in the season, after the middle of July. See eggs on apple twig, Plate III., Fig. 4.

Remedies.—For the destruction of the eggs, proceed as for the destruction of the eggs of the brown mite above. To destroy the lice, apply kerosene emulsion (14), or whale-oil soap (12), thoroughly and in a manner to bring the liquid in contact with the bodies of the lice.

SCALE INSECTS.

For the treatment of scale insects it is advisable, in each case, to write to the Experiment Station for specific directions. Specimens

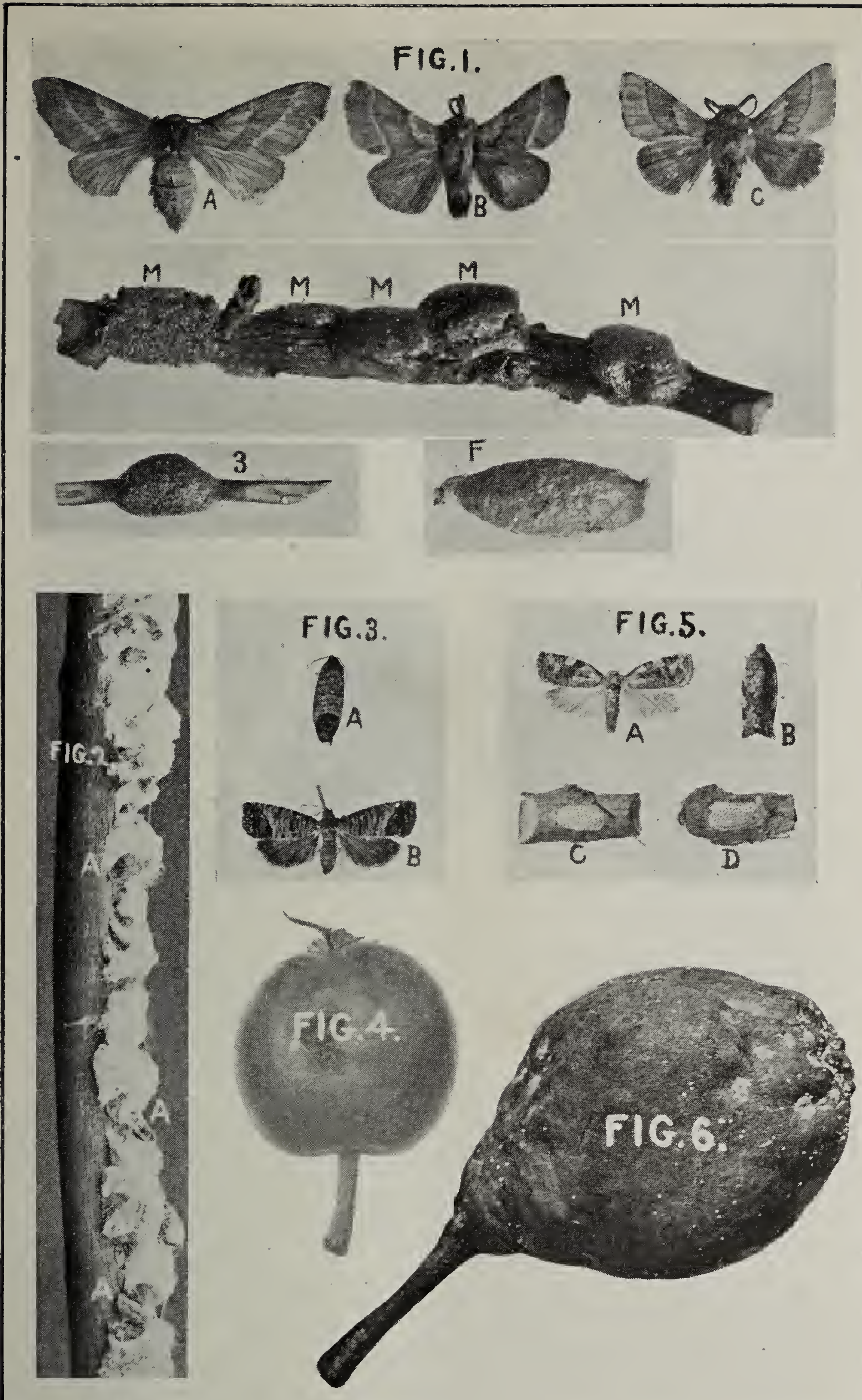

PLATE I.

Fig. 1—Western Tent-caterpillar: A, female moth; B, C, males. D, apple twig with egg masses (M). F, cocoon. 3, egg-mass of American Tent-caterpillar. Life size,

Fig. 2 -Cottony Maple scale: A, scales mostly hidden by secretion. Life size.

Fig. 3—Codling moth: A, wings closed; B, open. Enlarged about ¼.

Fig. 4—Apple showing white egg of Codling Moth (under letter F). Life size.

Fig. 5—Fruit tree leaf roller: A, moth, wings open; B, closed. C, D, egg patches, hatched. All life size.

Fig. 6—Pear with Howard's Scale. The young appear as minute white specks. Life size. Figures from photos by the author.

PLATE 2.

FIG. 1—Blossoms from which the petals have fallen and still in good condition to receive the spray. Also apples with the calyces closed.

FIG. 2—Spraying scenein orchard of Mr. Bergher, Palisade, Colo. Photos by the author.

of the scale should also be sent. Otherwise, use the treatment recommended for San Jose scale. See further on.

GRASSHOPPERS.

Several species. Those that fly from tree to tree can probably be managed best by means of arsenical sprays (3 to 8), when safe to use them.

Those that crawl up the trunks into the trees and jump to the ground when disturbed, can be quite largely kept out of the trees by arsenic bran-mash (2) used freely about the border of the orchard, and by sticky bands (38) of Raupenleim or printer's ink, or even cotton batting, about the trunks of the trees. If the Raupenleim or printer's ink is used, it should be spread upon a strip of cardboard which has first been wrapped about the trunk.

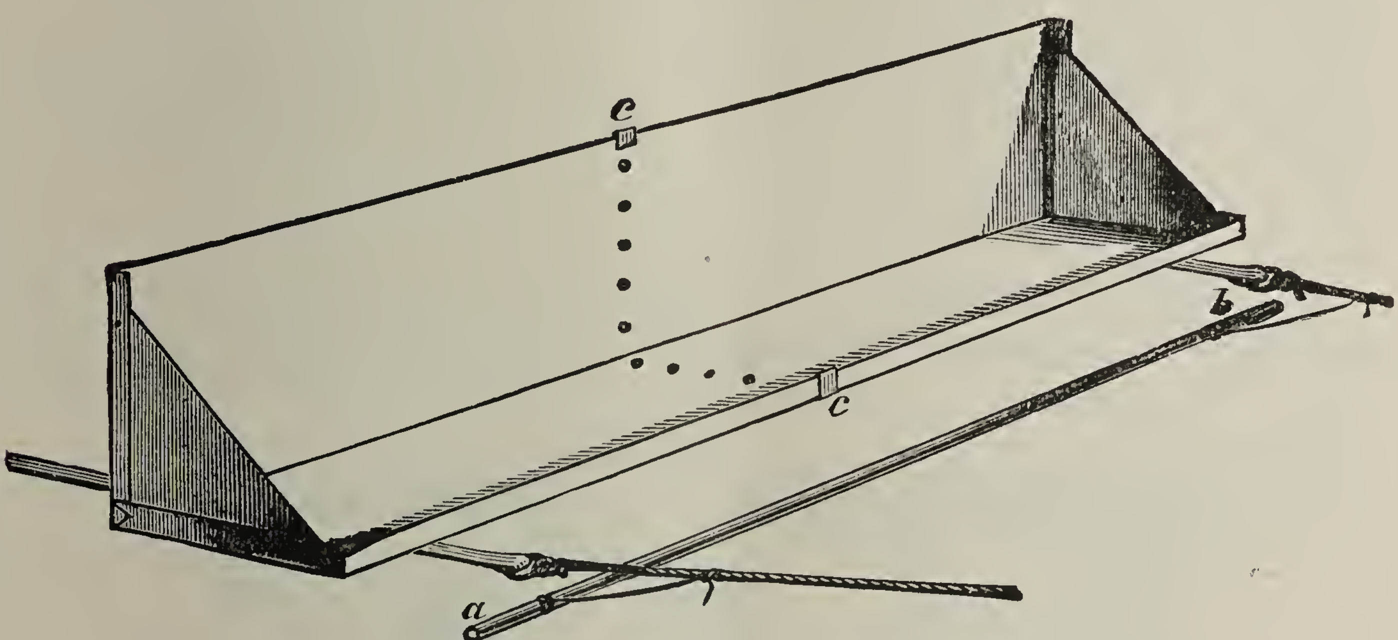

Fig. 2.—Hopper-dozer or Hopper-pan. (After Riley.)

Grasshoppers that injure orchards usually come from adjoining alfalfa or grass fields. In such cases the free use of the hopper-pan (37) in the alfalfa or grass field is the best remedy. One of the hopper-pans is shown at Fig. 2. At Fig. 3 female grasshoppers are shown in the act of depositing eggs in the ground.

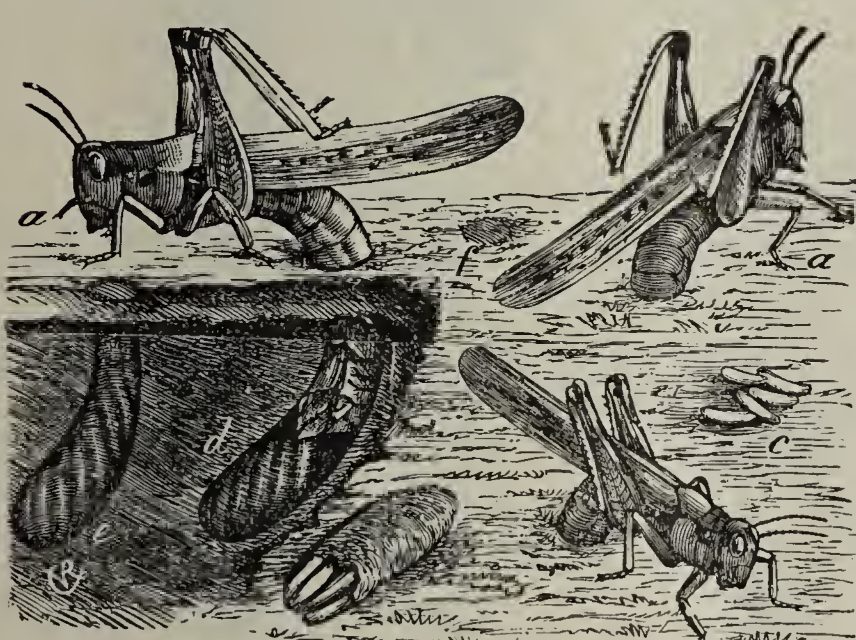

Fig. 3.—Rocky Mountain Locust, laying eggs in the ground: *a,a*, females with their abdomens in the ground; *b*, an egg-pod broken open; *c*, scattered eggs; *d*, egg-packet in the ground. (After Riley.)

ATTACKING TRUNK AND BRANCHES.

BORERS, FLAT-HEADED.

(*Chrysobothris femorata.*)

A whitish grub boring beneath the bark of apple and other trees and peculiar in appearance in seeming to have a greatly enlarged flat head. Fig. 4.

Remedies.—Remove with a pocket knife whenever found. Protect the south side of the trunks of the trees from the sun's heat, either by shading or white-washing during late winter and spring.

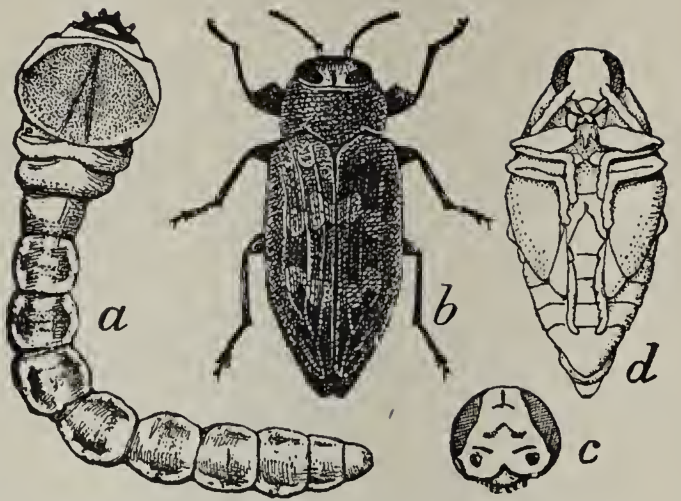

FIG. 4.—Flat-headed Apple-tree Borer: *a*, flat-headed larva; *b*, the mature beetle; *c*, head of mature beetle; *d*, pupa. All twice natural size. (Chittenden, Circular 32, U. S. Dep. of Agr., Div. of Entomology.)

APPLE TWIG-BORER. (*Amphicerus bicaudatus.*)

A cylindrical, mahogany-colored beetle, about one-third of an inch long, boring holes in twigs of apple, pear, cherry and other trees and grapevines. See Fig. 5.

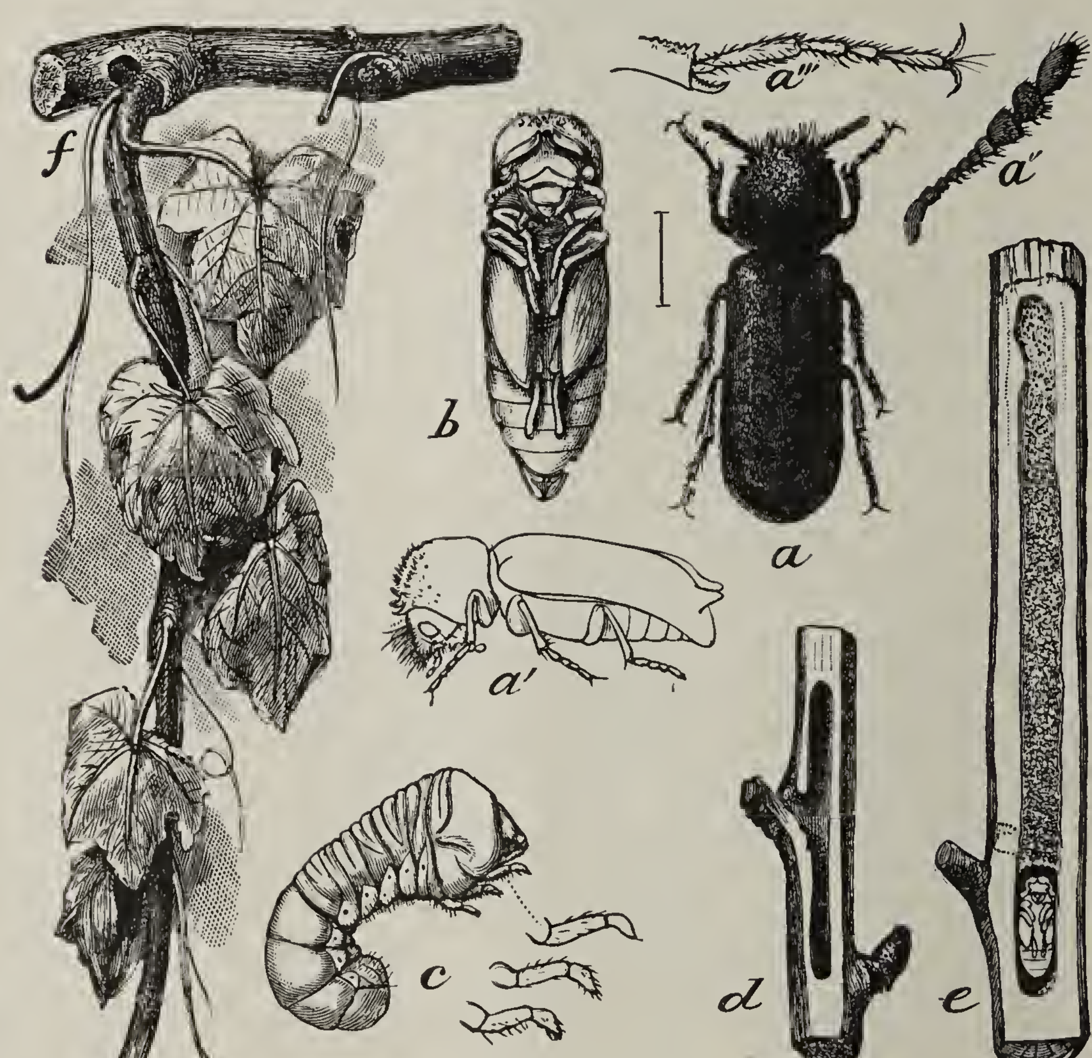

FIG. 5.—Apple Twig-borer: *a*, beetle dorsal view; *a'*, beetle side view; *b*, pupa from beneath; *c*, grub, side view; *d*, apple twig showing burrow; *e*, burrow in tamerisk with pupa at bottom; *f*, stem of grape showing burrow. All enlarged except stems showing burrows. (Marlatt, Farmer's Bulletin 70, Div. Ent., U. S. Dep. of Agr.)

Remedy.—Cut out the infested stems and destroy the borers.

BUFFALO TREE-HOPPERS. (*Ceresa* sp.)

Three-cornered, greenish to brownish insects, about a third of an inch in length. They jump when disturbed and puncture twigs of trees and stems of plants for the deposition of their eggs. From these punctures oval scars result. See Plate III., Fig. 3.

Remedies.—Infested twigs may be pruned away and burned. Probably clean culture is the best remedy. Keep down all weeds and unnecessary vegetation in and about the orchard.

SAN JOSE SCALE. (*Aspidiotus perniciosus.*)

This insect is very easily overlooked and may be present in sufficient numbers to kill trees before its presence is discovered by the orchardist. They may infest trunk, twig, fruit, or foliage. The scale is nearly circular, about one-sixteenth of an inch in diameter, dark gray in color with a rust-red spot at the center. Anyone finding such scales upon any tree should send examples at once to the Experiment Station for examination, as there are several species closely resembling each other in outward appearance. As yet this scale is unknown in Colorado orchards. See Plate I., Fig. 6, which shows a closely related species on pear.

Remedies.—Spray with lime, sulfur, and salt mixture (21) while the trees are dormant. Or, spray with whale-oil soap (12) in the proportion of two pounds to a gallon of water, or with crude petroleum (16) during winter. If trees are very badly infested, it will often be best to cut and burn them.

PUTNAM'S SCALE. (*Aspidiotus ancylus.*)

Very closely resembling the preceding species. Remedies the same.

SCURVY BARK-LOUSE.

(*Chionaspis furfurus.*)

Small white scales resembling scurf or dandruff on the trunk or branches. There are two sizes, the females are larger and oval, and the males are very small and slender. See Fig. 6.

Remedies same as for the San Jose scale.

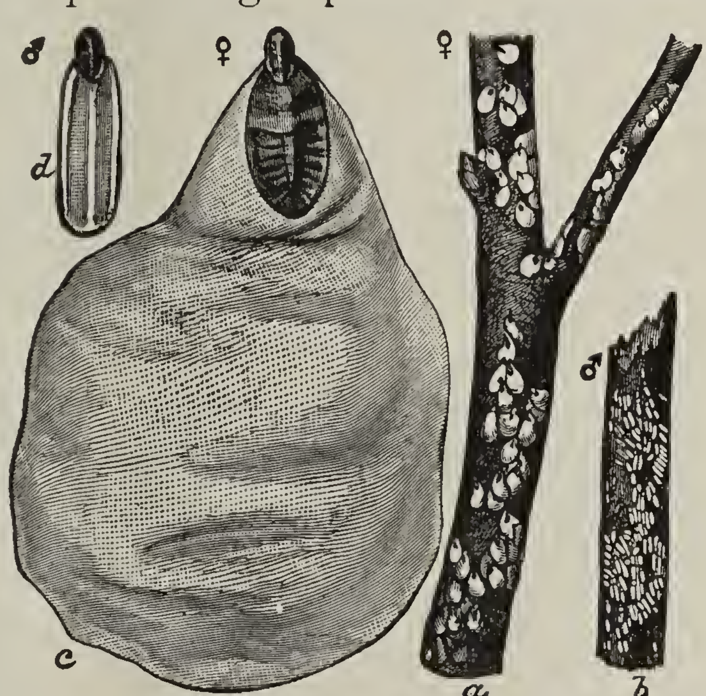

FIG. 6.—Scurvy Bark-louse: *a*, twig showing scales of female louse; *b*, twig showing scales of male louse; *c*, scale of female greatly enlarged; *d*, scale of male greatly enlarged. [Howard, Yearbook, U. S. Dep. of Agr., 1894.]

OYSTER-SHELL BARK-LOUSE. (*Mytilaspis pomorum.*)

Scales of the same color as the bark of the tree, about one-

eighth of an inch long, curved and small at one end. Very easily overlooked. See Fig. 7.

Remedies the same as for the San Jose scale.

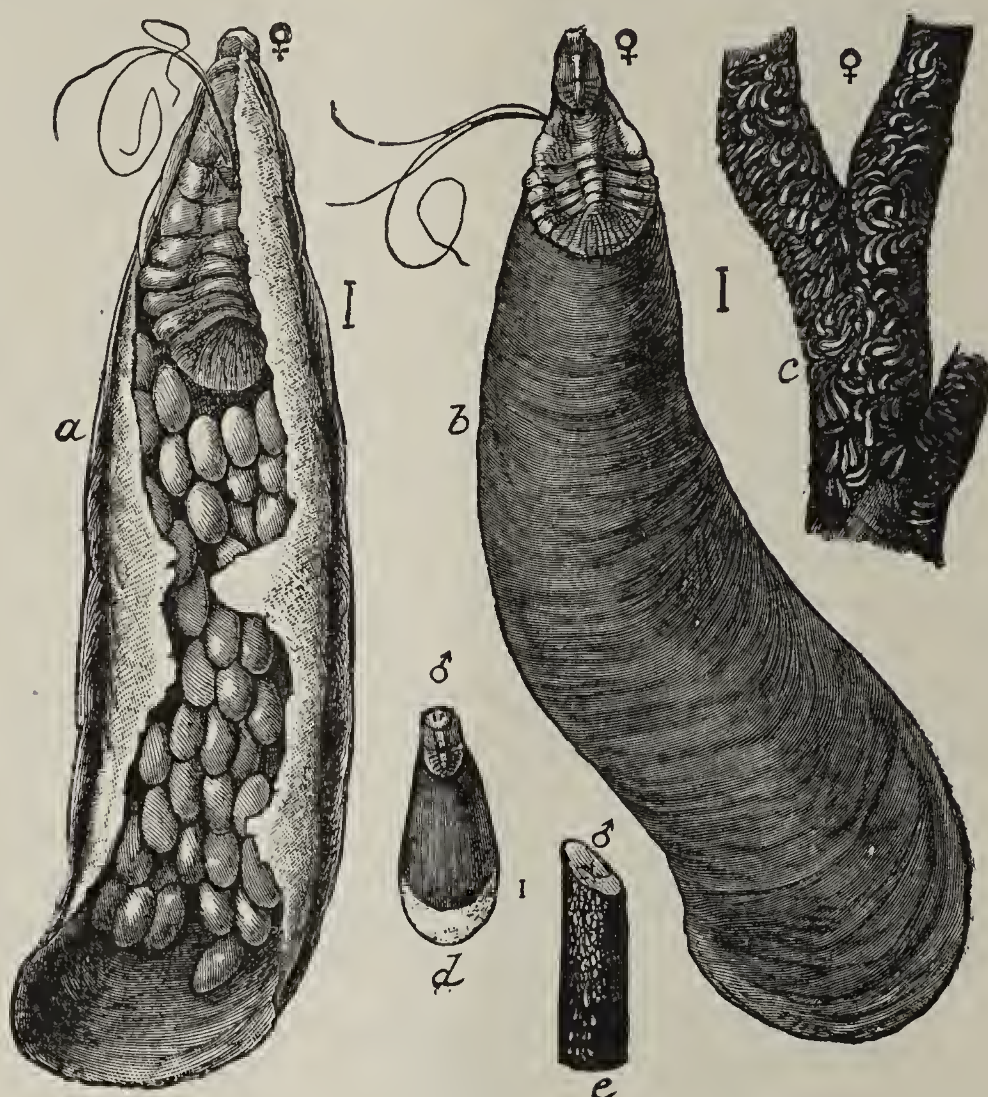

FIG. 7.—Oyster-shell Bark-louse: *a*, female scale from below, showing eggs greatly enlarged; *b*, the same from above; *c*, female scale on twig, natural size; *d*, male scale enlarged. [Howard, Yearbook, U. S. Dep. of Agr., 1894.]

WOOLLY PLANT-LOUSE. (*Schizoneura lanigera.*)

Small dark lice more or less densely covered with a white flocculent secretion. If the lice are crushed in the hand they leave a red stain. The lice attack chiefly tender bark about wounds or on tender growing shoots.

Remedies.—Early in the season, when the white patches begin to appear on trunk and branches, paint them over with pure kerosene (16), crude petroleum, or a very strong kerosene emulsion (14), or whale-oil soap (12) mixture. If the lice become abundant late in the season, apply kerosene emulsion or whale-oil soap in ordinary strengths but with a great deal of force and a coarse spray in order to wet through the waxy secretion which covers them.

This insect also attacks the roots. See Fig. 8.

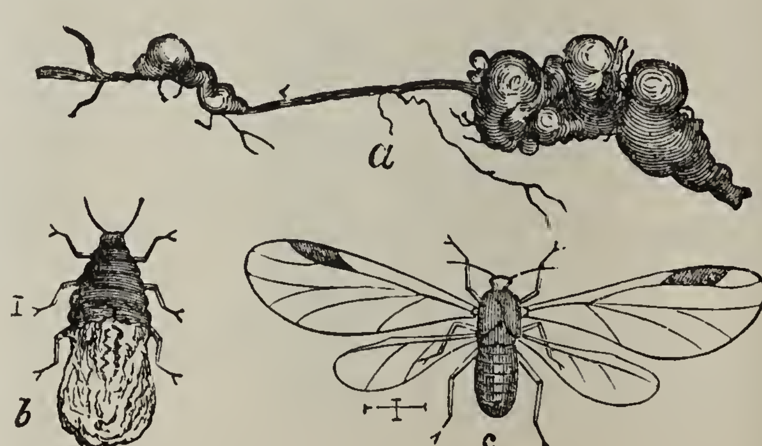

FIG. 8.—Woolly Aphis, root form: *a*, small root showing swellings caused by the lice; *b*, wingless louse showing woolly secretion; *c*, winged louse. (After Saunders.)

ATTACKING THE ROOTS.

WOOLLY PLANT-LOUSE. (*Schizoneura lanigera.*)

This insect attacks the roots as well as the trunk and branches. It causes warty excrescences and often the destruction of the greater portion of the smaller roots (Fig. 8). The description of the louse is the same as for the trunk form mentioned above.

Remedies.—Remove the earth about the crown for a distance of about two feet, put in four to six pounds of tobacco dust (or double this amount of stems) and cover again; then irrigate. If tobacco can not be procured, use kerosene emulsion (14) or whale-oil soap (12) of the ordinary strengths in its place, pouring in a liberal quantity.

INSECTS ATTACKING THE PEAR.

Any of the insects mentioned above as attacking the apple may be found attacking the pear, except the woolly plant-louse, and the same remedies should be employed.

PEAR-TREE SLUG. (*Eriocampa cerasi.*)

FIG. 9.—Pear-tree Slug: *a*, adult fly; *b*, larva or slug with the slimy covering removed; *c*, same as preceding in natural condition; *d*, leaves showing slugs and their injuries. (Marlatt, Circular 26, Second Series, U. S. Dep. of Agr., Div. Entomology.

Slimy dark-colored larvæ with the head end much the larger, somewhat resembling snails, resting upon the upper surface of the leaves, which they skeletonize. See Fig. 9.

Remedies. — Apply white hellebore, or any of the arsenical mixtures (3-8), by dusting or by spraying. Freshly slaked lime (20) or wood ashes (32) freely dusted upon the larvæ will kill many of them.

This is an easy insect to control and should not be allowed to continue the serious injuries to the pear, plum and cherry in this State that it has been doing the past few years.

PEAR LEAF-BLISTER. (*Phytoptus pyri.*)

Small dark spots upon the leaves, sometimes very abundant and involving the greater portion of the surface. The diseased portion is thickened also and at first is green like the rest of the leaf. The leaves often fall prematurely.

Remedies.—Spray the trees while dormant with kerosene emulsion (14), treble strength: whale-oil soap (12), one pound to two gallons of water; or with lime, salt and sulfur mixture. Gather and burn as many of the fallen leaves as possible.

HOWARD'S SCALE. (*Aspidiotus howardi.*)

Was found attacking pears badly in an orchard near Delta, Colo., last summer. This is a close relative of the pernicious, or San Jose scale, but, so far, has been known only upon plum and pear. Pears, or any fruit affected with scales, should be reported promptly to the Experiment Station. See Plate I., Fig. 6.

Remedies.—The same as for San Jose scale mentioned under apple insects.

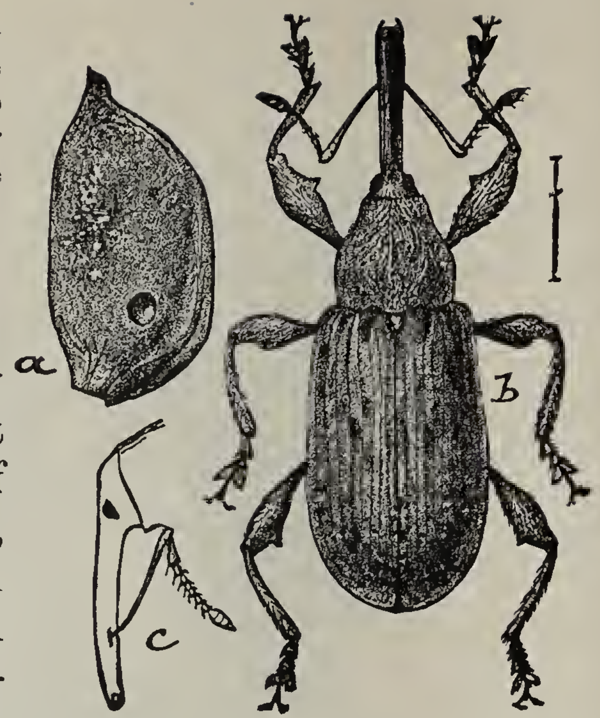

FIG. 10.—Plum Gouger: *a*, plum pit showing hole for exit of gouger; *b*, gouger; *c*, side view of head of gouger showing beak and antenna. (Riley & Howard, Insect Life, Vol. II., U. S. Dep. of Agr., Div. of Entomology.

INSECTS INJURIOUS TO THE PLUM.

ATTACKING THE FRUIT.

PLUM GOUGER. (*Coccotorus prunicida.*)

A small but rather robust snout-beetle about a quarter of an inch in length; color a leaden gray with head and thorax ocherous yellow; wing covers smooth without prominent humps on them. The beetle eats pin-holes in the growing plums in which it lays its eggs. The larva or grub eats into the pit and flesh on the kernel and later eats a hole out through both pit and flesh of plum just before the plum matures (Fig. 10). Attacks the red, or Americana varieties only. Only insect in Colorado injuring the fruit of the plum to any extent.

Remedies. — Jar the trees early every morning, or in the evening, from the time the blossoms are out till very few beetles can be obtained, catching them on a sheet spread beneath. It only takes a very few beetles to do a great amount of harm, as I have found by actual count that a single female may lay as many as 450 eggs.* Gathering and destroying all stung plums during the early part of July would nearly exterminate this insect. Spraying with an arsenical poison (4, 3, 6, 7, 5, 8) once, a few days before the trees blossom, and once or twice after, will give considerable protection. Use the poisons in two-thirds ordinary, or standard strengths. Arsenate of lead (5) is probably the safest to use on the foliage of the plum.

PLUM CURCULIO. (*Conotrachelus nenuphar.*)

This beetle is often confused with the preceding. As yet it has not been reported in Colorado. It is liable any year to appear in

*Insect Life, III., p. 227.

our orchards and all should be on the look out for it so as to do all possible to stamp it out or prevent its rapid spread. It is to the European varieties of plums what the codling moth is to the apples, only worse. The beetle is brown to blackish in color, is about one-fifth of an inch long and has two prominent humps and numerous smaller ones upon its wing covers. The beetle makes a crescent-shaped cut in the flesh of the fruit where an egg is deposited and the grub does not enter the pit but feeds on the flesh outside of it, causing the fruit to fall.

Remedies.—Jarring and spraying as in case of the preceding species.

Should anyone find what he thinks to be the work of this insect in his orchard, it is hoped he will notify the Experiment Station at once.

ATTACKING THE FOLIAGE.

FRUIT-TREE LEAF-ROLLER. (*Cacœcia argyrospila*)

See under apple insects. Use the poisons only two-thirds as strong on the plum as on the apple. Arsenate of lead is probably least likely to injure the foliage.

SLUGS.

Skeletonizing the upper surface of the leaves. See pear-tree slug. Use the same remedies.

BROWN MITE.

See under apple insects. Remedies the same.

PLANT LICE.

Two or three species attack the foliage of the plum badly in Colorado. Remedies the same as for apple plant-louse.

Other insects attacking apple foliage may be found on plum, where they are destroyed by the same treatment in either case.

ATTACKING TRUNK AND BRANCHES.

THE PEACH BORER. (*Sannina exitiosa.*)

This insect often attacks the plum. For its treatment see peach enemies.

FLAT-HEADED BORER.

See under apple enemies.

SCALE INSECTS.

See under apple enemies. When scales are found it will be well to send specimens to the Experiment Station for identification and advice. Howard's scale and Putnam's scale both occur on plum in the State. They have been injuriously abundant in a few isolated cases only.

INSECTS INJURIOUS TO THE CHERRY.

The insects attacking the cherry in Colorado are the Fruit-tree Leaf-roller, Tent Caterpillar, Fall Web-worm, Brown Mite, Plant Lice, Scale Insects, Grasshoppers, Flat-headed Borer, Twig Borer, Buffalo Tree-hoppers and Pear Slug mentioned above.

INSECTS INJURIOUS TO THE PEACH.

PEACH TWIG-BORER. (*Anarsia lineatella.*)

This is the worst peach enemy in Colorado at the present time. As soon as the buds begin to open in the spring, a small brownish larva with a black head eats into the buds and destroys them. When the new shoots start, the borer eats into them causing them to wilt and die. Many of the second brood of this borer eat into the peaches, causing a gummy exhudation and ruining them for market. The larvæ that appear in the spring spent their winter in little excavations which they made in the fall in the bark of the trees. See Figs. 11 and 12.

Remedies.—Early in the spring, just before the buds open, spray the trees with lime, salt and sulfur wash (21), whale-oil soap (12) in the proportion of a pound to two gallons of water; fish-oil soap (13) diluted once with water, or kerosene, will doubtless do the work nearly or quite as well as the lime, sulfur and salt. Many of the larvæ may be caught under bandages (36) used as for the codling moth.

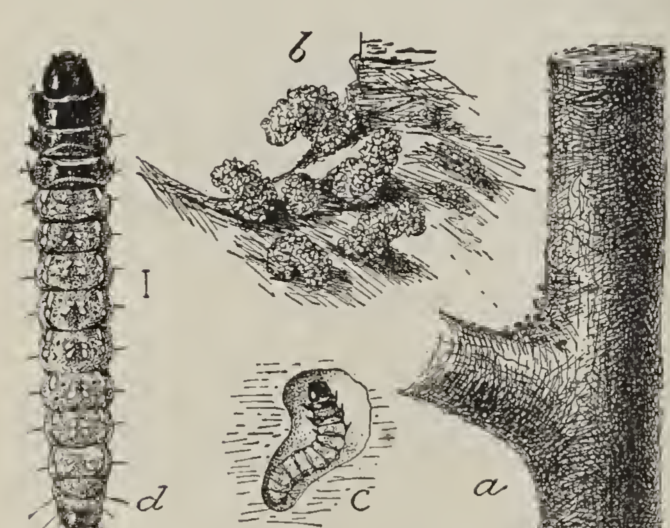

FIG. 11.—Peach Twig-borer: *a*, twig of peach showing little masses of chewed bark above the larval burrows; *b*, the same enlarged; *c*, larva in winter burrow, enlarged; *d*, hibernating larva greatly enlarged. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology).

FIG. 12.—Peach Twig and Borer: *a*, young shoot wilting from attack of borer; *b*, adult larva enlarged; *c*, chrysalis enlarged; *d*, tail end of chrysalis showing hooks. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology.)

THE PEACH BORER.

A yellowish white borer attaining the length of about one inch, boring beneath the bark of the lower trunk and larger roots. See Plate IV.

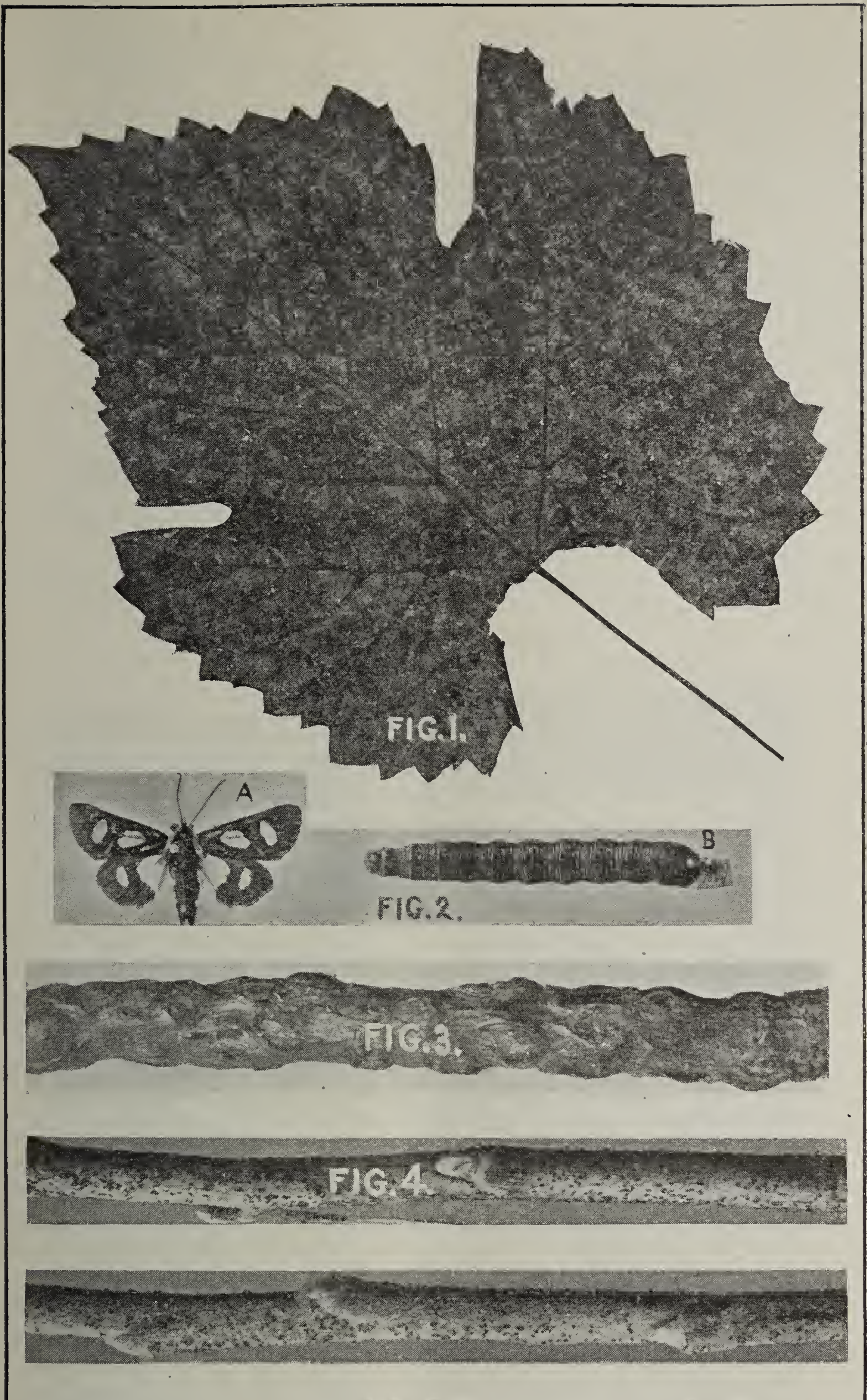

PLATE 3.

FIG. 1—Grape leaf showing bleached appearance due to grape-leaf hopper (*Typhlocyba comes*).

FIG. 2—Eight-spotted Forester (*Alypia 8-maculata*): A, moth; B, larva. Nearly life size.

FIG. 3—Apple twigs injured by Buffalo Tree-hopper (*Ceresa sp.*) Life size. Photos by author

Fig. 1—Moths of Peach Borer.

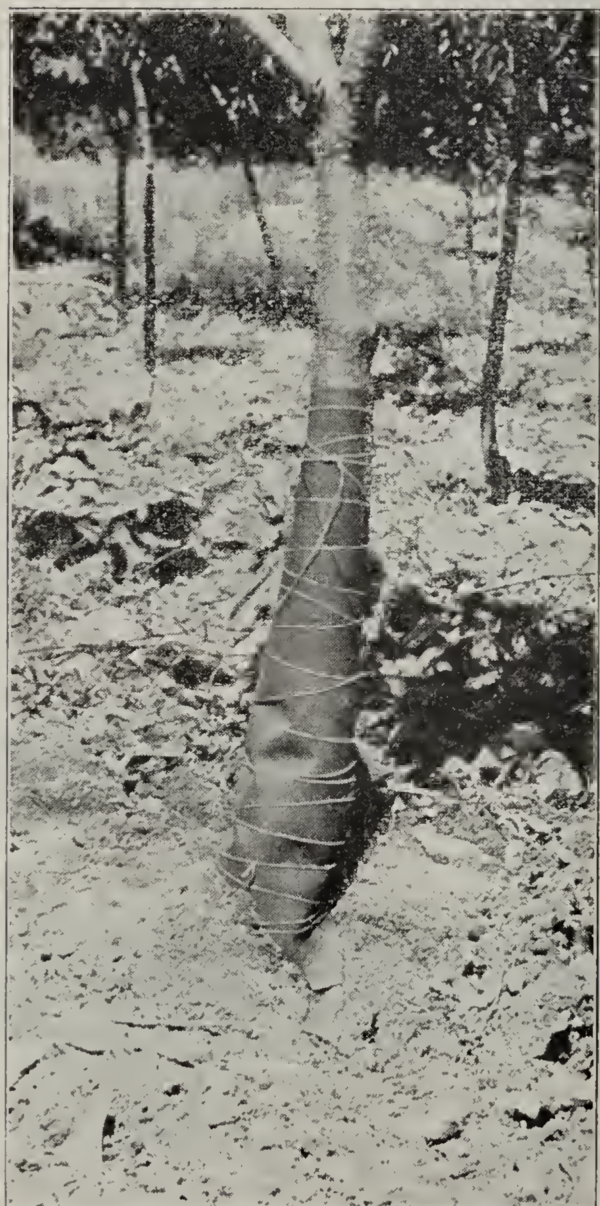

Fig. 2—Peach tree bandaged with paper.

Fig. 3—Peach tree with wire screen. All after Slingerland, (Bull. 176, Cornell Expt. Station.)

PLATE 4.

Remedies.—Carefully inspect the trees every fall and spring, remove some of the earth next the crown, and search for and remove the borers with the aid of a pocket knife. Their presence is usually indicated by the exhudation of a gummy material upon the bark. Shields of stout paper or wire screen placed about the trunks and left there from the 1st of May till the 10th of July will serve as a means of protection from egg-laying. The paper screen is the better. (See Plate IV., Figs. 2 and 3.

PLANT LICE.

The plant lice that attack the foliage of the peach may be treated in the same way as the apple plant-louse mentioned above. The black peach aphis, which does its chief injury to the roots, should be handled in the same manner as the woolly louse of the apple.

INSECTS INJURIOUS TO THE GRAPE.

THE ACHEMON SPHINX. (*Philampelus achemon.*)

Hairless caterpillars devouring the leaves. When small, the caterpillar have each a long dorsal spine on the last segment of the body. When nearly grown, the spine is represented by a shining black spot. These larvæ resemble the large tomato "worm."

Remedies.—Any of the arsenical poisons may be used as recommended for apple leaf-rollers. Pyrethrum (24) may also be used as a powder or spray, but to kill it must come in contact with the caterpillars. Hand picking is the best remedy in a small vineyard.

This insect is also bad on Virginia creeper.

THE EIGHT-SPOTTED FORESTER. (*Alypia octomaculata.*)

A dark-colored caterpillar, about one and one-half inches long when fully grown. A close examination will reveal numerous small black and white cross lines and a few red ones to each body segment. See Plate III., Fig. 2.

Remedies.—The same as for the preceding species.

This insect also infests the Virginia creeper.

BORER.

See apple twig-borer, which also attacks the grape.

TREE CRICKETS. [*Œcanthus* sp.]

The female cricket punctures stems of grape and other plants and in each puncture deposits a long cylindrical egg. The punctures are usually in rows lengthwise of the stem and look like needle thrusts.

Remedies.—Cut out badly infested stems. Keep the vineyard clean of all weeds.

COTTONY SCALE. [*Pulvinaria innumerabilis.*]

This scale, commonly found infesting soft maple, sometimes attacks grapevines. See Plate I., Fig. 2.

Remedies.—When the little lice first hatch from the scales, about the last of June, the ordinary sprays of kerosene emulsion (14) or whale-oil soap (12) will

destroy them. If the spraying is delayed till a heavy scale has formed over the lice, stronger applications will be required.

GRAPE FLEA-BEETLE. [*Graptodera chalybæa.*]

A small steel-blue beetle appearing early in the spring and again in midsummer and feeding upon the foliage. The beetles deposit eggs which soon hatch into small dark-colored larvæ which also eat holes in the leaves.

Remedies.—Arsenical poisons (3-8) sprayed or dusted upon the foliage. If unsafe to use poisons, dust freely with Pyrethrum (24).

GRAPE LEAF-HOPPERS. [*Typhlocyba* sp.]

Small jumping and flying insects, often called "grape thrips." The insects often fly out from the vine in great numbers when the latter is jarred and return quickly to the under side of the leaves. As a result of the punctures and the extraction of the sap, the leaves lose their dark green color and at first are minutely specked and freckled with white, as shown at Plate III., Fig. I. Later the leaves shrivel and die. The red spiders, brown mites and thrips cause a similar appearance of the foliage they attack.

Remedies.—Spray forcibly with kerosene emulsion (14), kerosene and water (16), or whale-oil soap (12) very early in the morning while the insects are dormant and drop readily from the leaves. Burn dry leaves, dead grass and other rubbish in the vicinity of the vineyard during winter or early spring, on a cold day.

GRASSHOPPERS.

Remedies.—Use arsenical spray (3-8) where safe. If not safe to spray, use the arsenic-bran mash (2) freely about the borders of the vineyard and about the vines. Make free use of hopper-pans (37) in adjoining fields to reduce the number of hoppers before they reach the vineyard. Plow or thoroughly harrow the ditch banks and the borders of the field late in the fall to destroy as many of the eggs as possible.

INSECTS INJURIOUS TO THE CURRANT.

IMPORTED CURRANT-BORER. [*Sesia tipuliformis.*]

Yellowish white larvæ burrowing in stems, giving rise to wasp-like moths in June. The moths closely resemble those of the peach borer, shown at Plate IV., Fig. 1.

Remedies.—Cut out the infested stems and burn them during winter or early spring. Also keep the old wood well trimmed out of the bushes.

CURRANT SAW-FLY. [*Pristiphora grossulariæ.*]

A green larva, about half an inch long when fully grown, feeding upon the leaves of currant and gooseberry bushes. Appearing late in June and again about the last of August. The adult insect is a black four-winged fly about the size of a house-fly. The eggs are deposited, one in a place, under the epidermis of the leaves.

Remedies.—The best remedy for this pest is white hellebore (9) dusted ightly over the foliage in the evening. If this is carefully done, nearly every

larva can be found dead under the bushes next morning. Arsenical sprays (3-8) may be used either dry or in water, as for other leaf-eating insects. These poisons should not be used before the currants are picked. Pyrethrum (24) may be safely used at any time.

INSECTS INJURIOUS TO THE STRAWBERRY.

STRAWBERRY LEAF-ROLLER. [*Phoxopteris fragariæ.*]

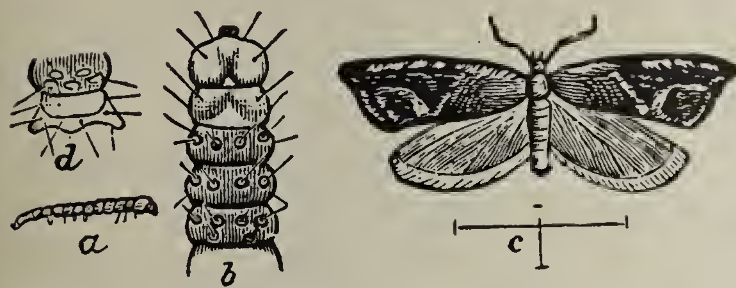

FIG. 13.—Strawberry Leaf-roller: *a*, larva, natural size; *b*, head end of larva enlarged; c, moth about twice natural size; *d*, tail end of larva enlarged. (After Saunders.)

Small brownish or greenish larvæ attaining a length of nearly half an inch and having the habit of folding the leaves of the strawberry. In these folds the larva lives and feeds and finally changes to a small rust-colored moth with white markings on the wings. See Figs. 13, 14.

Remedies. — When the fruit has been gathered, scatter straw over the vines and burn it. Arsenical sprays (3-8) may be used, but the worms are so protected in the folded leaves that it is difficult to get a poisonous dose to them. The vines will put up a good growth of tops after the burning, if it is not done too late.

STRAWBERRY CROWN BORER

[*Tyloderma fragariæ.*]

A small yellowish white grub boring into the crown of the plant during summer.

Remedies. — Burning as for the preceding species will destroy a large proportion of the borers. Do not allow the plants to become very old, but plow frequently as soon as the berries are picked and start a new bed at some distance from the old one. Poisons are of doubtful value.

FIG. 14.—Strawberry leaves showing their appearance after being folded by the roller. (After Weed.)

PART II.

INSECTICIDES.

THEIR PREPARATION AND USE.

In order to be able to apply insecticides intelligently and with success, it is important to understand something of the habits of the particular insects to be destroyed and also of the nature of the remedies to be used. Many insects, like grasshoppers and the potato beetle, devour the surface tissue of plants, while others, like plant-lice, squash-bugs, and scale insects, insert sharp tubular beaks into the tissues of plants and suck the sap from beneath the surface. Insects of the first class may nearly always be destroyed by means of food-poisons, such as arsenic, Paris green, hellebore, etc., while those of the latter class are unaffected by food-poisons and have to be killed by substances that come in contact with the surface of their bodies, or in some other manner. It is not necessary to be a skilled entomologist in order to determine which class of insects are doing injury to the plants in question. If the leaves are ragged or eaten full of holes, it is practically certain that the injury is being done by an insect with biting mouth-parts. If the leaves simply wilt and dry up without having the tissue eaten away, the insect doing the injury is of the second type mentioned. The most common remedies for this class of insects are kerosene emulsion, whale-oil soap, crude petroleum, and lime-sulfur and salt washes.

In many cases it is impossible to get an insecticide upon the insect that it is desired to kill, or upon its food, and then other means have to be used to prevent the injuries. Borers, underground feeders upon roots, and weevil living in seeds, are examples of such insects.

In the pages that follow I shall not attempt to treat of all the methods used to destroy insects or avoid their injuries, but the more important ones only.

SUBSTANCES THAT KILL BY BEING EATEN.

Nearly all the food-poisons have for their active principle arsenious acid, or white arsenic ($AS_2 O_3$). White hellebore and borax are about the only exceptions.

1. WHITE ARSENIC.

While this is the cheapest of the arsenical poisons, it is used but little, except for the purpose of making arsenical compounds with other substances, such as lime, copper and lead. Because some States have passed laws requiring a high percentage of arsenic in Paris green, arsenic has been used as an adulterant of Paris green and thereby working an injury to the purchaser if not a benefit to the manufacturer of it, because arsenic is much cheaper than Paris green, and when it is mixed with the latter it greatly increases its liability to burn foliage. The reason that white arsenic burns foliage badly is it dissolves in water and, when in solution, it penetrates the leaves and kills the living tissue. Arsenical mixtures must *never be in solution, but only in suspension*, in the water that is used to distribute them upon foliage.

2. ARSENIC BRAN-MASH.

Prepared by mixing one pound of arsenic and six to ten pounds of bran together, with just water enough to thoroughly moisten the mass. Some prefer to add a pound of sugar to the above in order to cause the particles of bran to adhere to each other, so that it may be distributed in little balls pressed together with the hands or with a paddle. This poisoned bran is used for the destruction of grasshoppers in orchards and vineyards where it is not possible to use a hopper-pan.

3. PARIS GREEN.

This poison in a pure state is said to be composed of three substances—arsenious acid, acetic acid, and copper oxide—united in a chemical combination. The percentage of arsenic may vary considerably, as these substances do not always combine in exactly the same proportions. The range is nearly always between 55 and 60 per cent arsenic, with an average of about 58 per cent. *Mr. J. K. Haywood, one of the chemists in the Department of Agriculture at Washington, D. C., says that the chemical composition of Paris green should be:

	Per cent.
Arsenious acid	58.65
Copper oxide	31.29
Acetic acid	10.06

Pure Paris green is one of the very best of the arsenical compounds for the destruction of insects, and the reports of many analyses in different States do not indicate that this poison is often found greatly adulterated upon the market. If adulteration is suspected, or if the poison is being purchased in any considerable quantity, it is advisable to test its purity in some way. Pure Paris

*Farmer's Bull. No. 146, U. S. Dept. of Agr.

green is entirely soluble in ammonia, giving a clear blue liquid. If any particles can be seen floating through the liquid or settling to the bottom, the article is not pure. If the ammonia dissolves all, there can be little doubt that it is pure. This is a test that anyone can make. The particles of Paris green are entirely bright green in color and globular in form, and the presence of an adulterant can be most easily detected under a microscope of moderate power. Prof. Woodworth of the University of California explains another method by which impurities can usually be detected in Paris green. It is by placing a small amount of the poison on a clean piece of glass and then slanting the glass and jarring it so as to cause the powder to slide to the lower side. If this is done carefully the adulterants, which are not green in color, will fall behind and can be detected with the unaided eye.

Where there are several persons in the same neighborhood wanting this poison, it is best for all to order together and then send a sample to a chemist for analysis. If a good number unite in this way the Station chemist, most likely, would be willing to make the test free.

Application of Paris Green to Plants.—The arsenical mixtures are usually applied in a watery spray, and the most common strength is:

Paris green	1 pound
Water	160 gallons
Lump lime (freshly slaked)	2 pounds

On very sensitive foliage, like that of the peach, apricot, nectarine and bean, it would be safer to use 200 gallons of water to a pound of the poison. A pound to 100 gallons is quite safe for applications upon apple, cherry, cabbage, beets, potatoes, and most other trees and plants in the dry atmosphere of Colorado. The poison always should be placed in a small quantity of water first and thoroughly stirred in and then poured into the full amount of water to be used.

The chief objection to the use of Paris green as an insecticide is its high specific gravity, which causes it to settle rapidly in water. Pumps used to apply this poison always should have some means of keeping the water well stirred.

Dry applications may be made in various ways. Sometimes the poison is used pure, in which case the lightest possible dusting is made over the plants. It is usually better to dilute the poison with about twenty times its own weight of flour, plaster or lime, when a more liberal dusting may be made. This method is more economical of the poison and enables one better to tell when all parts of the plant have been treated. A good proportion is:

Paris green	1 pound
Common flour	20 pounds

The advantages of flour over lime or plaster are, it helps better to stick the poison to the leaves and is not distasteful to insects. Particles of poison imbedded in a mass of plaster or lime would probably be avoided by most insects. Filling the blossom ends of apples with lime mixed with poison will drive the worms to eat their way into the apple, where they will probably escape the poison entirely.

The methods of applying dry poisons are chiefly two. If low plants, like cabbages and tomatoes, are to be treated, and the area to be covered is not too great, a very satisfactory method is to make a small sack—about ten inches long by five inches in diameter—of strong cheesecloth or other light muslin, fill half full with the mixture of poison and flour and then shake or jolt the sack over the plants.

Where large areas are to be treated, or where it is necessary to make the application to trees or high bushes, some kind of dust gun or bellows is an advantage. Powder guns of different kinds are upon the market and some of them are being extensively advertised at this time. These instruments have an important place to fill, but I doubt very much if they can take the place of the watery spray for large trees, and particularly for the application of poisons for the destruction of the codling moth.

4. SCHEELE'S GREEN (GREEN ARSENOID).

Scheele's green, also sold as "green arsenoid," differs very little from Paris green in chemical composition, except in lacking the acetic acid. It is considered as effectual as an insect destroyer, and has a great advantage over Paris green in being much more finely divided, so that it remains in suspension in water for a much longer time. It is also cheaper in price. Dr. Marlatt, of the Division of Entomology, says it should replace Paris green as an insecticide.

Apply either wet or dry, as recommended for Paris green.

5. ARSENATE OF LEAD.

This compound contains only about 25 per cent. of arsenic acid, but has some advantages over the other arsenical compounds. It is so completely insoluble in water that it may be used in almost any strength without injuring foliage and consequently is least likely to injure plants that are most sensitive to arsenical poisons. When suspended in water this poison takes the form of a flocculent precipitate that remains suspended a long time without settling, and consequently can be more evenly distributed than most arsenical mixtures. Its third point of superiority is in its adhesive qualities when applied to foliage. Applications made to foliage in the latter part of May at this Station could plainly be seen upon the leaves the first of September. The disadvantage of the poison is in its not being as destructive to the insects that eat it as are the other

arsenites, consequently it is necessary to use it in stronger mixtures.

To prepare arsenate of lead, dissolve in water arsenate of soda and acetate of lead (white sugar of lead) in the proportion of three pounds of the former to seven pounds of the latter. Then use not less than two or three pounds of the combined chemicals to each hundred gallons of water. Three or four times this strength will do no harm to foliage.

6. ARSENITE OF LIME.

White arsenic and lime may be made to combine, forming an arsenite of lime that is practically insoluble in water. The poison may be prepared in either of two ways. What is known as the Kedzie formula is as follows:

> "Boil two pounds of white arsenic and eight pounds of sal-soda for fifteen minutes in two gallons of water. Put into a jug and label '*poison*,' and lock it up. When ready to spray, slake two pounds of lime and stir it into forty gallons of water, adding a pint of the mixture from the jug."

The other method is to boil together arsenic, lime and water for a full half hour in the following proportions:

White arsenic	1 pound
Lump lime	2 pounds
Water	3 gallons

Then dilute to 200 gallons of water before applying to foliage.

These preparations have become very popular in the past two years and deservedly so. White arsenic is cheap and consequently is in very little danger of adulteration, so that one is almost certain of the strength of his mixture when using this poison. Care must be taken, however, to *use fresh, unslaked lime of good quality.*

Before being diluted for use, the mixture should be passed through a coarse cloth or sieve, to take out the lumps that would otherwise clog the spraying nozzle.

7. LONDON PURPLE.

London purple is a by-product in the manufacture of aniline dyes and has for its active principle arsenite of lime. It also contains some free arsenic, lime, coloring matter and other impurities. The amount of arsenic present is subject to considerable variation, but will usually range between 40 and 55 per cent. As there is often considerable soluble arsenic present, it is always best to use a pound or two of freshly slaked lime with every pound of the poison if used in water.

This poison is finely divided and remains in suspension in water much longer than does Paris green, and it usually sells at about two-thirds the price of that poison. It seems to be going into disfavor because of its variable composition and the danger of its

burning foliage. It is also considered somewhat less effectual in killing insects than is Paris green or Scheele's green. It should compare favorably, however, with the prepared arsenite of lime in its power to kill insects, and there is little danger that it will be adulterated, as it is a waste product.

Apply either wet or dry in the manner and in the same proportions as are previously recommended for Paris green, being sure to add a pound or two of freshly slaked lime for each pound of poison if used as a spray.

8. BORDEAUX MIXTURE AND THE ARSENITES.

Bordeaux mixture is a fungicide and is the substance most often used for the destruction of fungi that attack the surface of plants. It has been found to be of value for use against flea-beetles, and the writer also demonstrated its value a number of years ago as a medium in which to spray Paris green or London purple. These poisons can be used very strong in this mixture without injury to foliage and they do not in the least lessen its effect as a fungicide. Such a mixture will destroy both insects and fungi with one application.

Bordeaux mixture may be prepared as follows: Take of

Copper sulfate	4 pounds
Quicklime	4 pounds
Water	45 gallons

Dissolve the copper sulfate in a gallon of hot water, slake the lime in another gallon of water, and then add the milk of lime slowly to the copper sulfate solution while the latter is being constantly stirred. Then add 43 gallons of water.

If insects are to be killed at the same time, add to the above quantity of Bordeaux mixture one-third pound of London purple, Paris green or Scheele's green.

9. WHITE HELLEBORE.

Hellebore, as obtained from drug stores, is a light, yellowish-brown powder. It is a vegetable poison and is obtained by pulverizing the roots of a European plant, *Veratrum album.* It is not as poisonous as the arsenites and consequently is not as effective in the destruction of most insects, but it has its special uses. Slugs, which are the young of saw-flies, are particularly susceptible to its effects. The poisonous property is an alkaloid and it loses its virtue after being exposed to the air for a few days. For this reason it can not be used where it is likely to remain long before being eaten, and it must be kept in tight receptacles and must not be kept too long before using. It is often useful for the destruction of insects upon plants containing fruit that will soon be used for food.

Dry applications are easily made upon low plants by making a

small cheesecloth sack, through which the dust may be sifted lightly over the foliage. The best time to apply is in the evening.

In the wet way use

White hellebore	1 ounce
Water	3 gallons

Apply as a spray in the evening.

10. BORAX.

Used chiefly for the destruction of cockroaches. Spread the powdered borax upon bread, sweet potato or banana peelings, or mix with sweetened chocolate, and place the bait where the cockroaches can get at it.

SUBSTANCES THAT KILL BY EXTERNAL CONTACT.

Substances in this group are chiefly used against insects that take liquid food from beneath the surface of the plant by means of a tubular rostrum or beak, but they may be used against many other soft-bodied insects with success. Insects having a hard outer crust to their bodies resist these substances and are not easily killed by them. If insects are covered with a powdery or cottony material, the insecticide will have to be applied with considerable force to cause it to penetrate to the body. Applications must always be thorough, because only those insects will be killed that have the substances thrown upon them.

11. SOAP.

The ordinary soft soaps and laundry soaps have long been used for the purpose of killing vermin on plants and animals, and they have considerable insecticidal value, particularly for the destruction of very tender insects, like plant lice. There are two kinds of soap that are specially useful for the destruction of insects, and these are whale-oil soap and fish-oil soap.

12. WHALE-OIL SOAP.

For ordinary plant lice one pound of the soap to eight or ten gallons of water is sufficient if the application is thorough. Double this strength will not injure most plants and is often required to destroy more resistent insects. For scale lice, like the San Jose scale for example, it is used as strong as a pound, or even two pounds, to a gallon of water. These strongest applications can only be used in the winter or early spring when the trees are dormant. The soap is more effectual if applied when quite hot.

13. FISH-OIL SOAP.

Lodeman in his "Spraying of Plants" gives the following formula for the preparation of fish-oil soap:

Potash lye	1 pound
Fish-oil	3 pints
Soft water	3 gallons

Dissolve the lye in boiling water and then add the oil and boil for two hours longer. Before using dissolve a pound of this soap in from six to ten gallons of water. Use for the same purposes as whale-oil soap, and in the same strengths.

14. KEROSENE EMULSION.

This preparation is probably the best general purpose insecticide for the destruction of insects by external contact. The materials composing it are always at hand and it is not difficult to prepare after one has had a little experience. Soft water should be used, if possible. If very hard water is used it may be necessary to "break" it first by adding washing soda or potash lye.

To make the emulsion use the ingredients in the following proportions:

Soap	1 pound
Kerosene	2 gallons
Water	27 gallons

Prepare by dissolving the soap in a gallon of water, then, while the soapy water is boiling hot, remove from the fire and immediately add two gallons of kerosene and agitate briskly for a few minutes. If a large amount is being made use a force pump and forcibly pump the mixture back into the receptacle that contains it until all is a frothy, creamy mass. If such a mixture is not obtained in a very few minutes, put the whole over the fire again until it boils and then repeat the pumping, and the emulsion will almost surely form. When put back for reheating *watch every moment to see that it does not boil over and take fire.* This work should be done out of doors. After the emulsion is made, add the remaining 27 gallons of water and all is ready for use.

Small quantities may be emulsified with a rotary egg-beater.

Whale-oil soap, or any cheap laundry soap, may be used.

Clean dishes and clean water should be used. Every particle of dirt in the emulsion serves as a center of attraction about which the oil droplets will collect and then rise to the top to form a film of oil on the surface.

The strength above given is suitable for most insects. Most plant lice may be killed with an emulsion of half the above strength.

15. KEROSENE-MILK EMULSION.

Kerosene will emulsify with milk, also, and when small quantities are wanted it is often less trouble to use the milk than to prepare the soapy water. The proportions are:

Milk (sour)	1 gallon
Kerosene	2 gallons

Dilute with water as in the preceding formula. If sweet milk is used add a little vinegar. Otherwise it may be impossible to form a stable emulsion.

16. KEROSENE AND CRUDE PETROLEUM.

These oils are used pure, and also diluted with water, for the destruction of scale and other insects. Experiments in the Eastern States seem to indicate that the safest time to apply is early in the spring, just before the buds swell, and on a bright, windy day when the oil will evaporate rapidly. It seems that when applied in moderation, in the proporiion of 40 parts of the oil to 60 of water, these substances will seldom injure apple, cherry or pear trees, but can hardly be applied to tenderer trees, such as peach and plum, without farther dilution.

When diluted with water in the form of a spray they may be used upon foliage of most plants, without injury, in the proportion of one of the oil to five or six of water. Most plant lice are killed in mixtures as weak as one to fifteen or twenty.

Pumps are now made for the purpose of mixing the oil and water in the form of a spray, and so doing away with the need of preparing an emulsion. The one who has the insecticides to apply must decide whether or not he will go to the extra trouble of making the emulsion or whether he will go to the extra expense of purchasing a special and somewhat more costly pump.

17. GASOLINE.

This oil is also destructive to insect life. Its chief use is for the destruction of bed-bugs. It is applied pure by means of an oil-can or hand atomizer. To be effectual the bugs must be thoroughly treated with it. As it is inflammable, care must be taken not to bring fire near until the apartments where it is used are well aired.

18. TURPENTINE.

Turpentine is used for the same purposes as gasoline and the same precaution applies.

19. LYE AND WASHING SODA.

These substances are in considerable popular favor for the destruction of insects, but the writer's experience with them has not been encouraging. In the proportion of a pound to three gallons of water they may be used upon the trunks of trees and will kill soft-bodied insects that might be wet by them. To be used upon foliage they should be diluted to a pound to forty gallons of water, and in this strength they will only destroy the tenderest of insects. Kerosene emulsion or whale-oil soap are much more effectual insecticides.

20. LIME.

Lime, either wet or dry, may be used freely upon foliage without fear of injury. It is of very little value as an insecticide. When freshly slaked and freely dusted upon the slugs that infest pear, cherry and plum trees it is said to be very effectual in destroying them. Experiments at this Station have not succeeded very well in killing slugs this way. As a coating upon the bodies of fruit trees it undoubtedly does much to prevent sun-scald late in winter and early in spring. The addition of a liberal amount of skim-milk or salt, or both, to the preparation will greatly increase its adhesive qualities. The following formula is printed in the 1899 report of the Canada Experimental Farm:

Skim-milk	6 gallons
Water	30 gallons
Lime	60 pounds
Salt	10 pounds

21. LIME, SALT AND SULFUR WASH.

This wash, when properly made, is one of the most effectual applications for the destruction of scale insects and eggs of the brown mite, particularly in dry climates, like that of Colorado. It should be used only in the winter or spring, while the trees are dormant. The ingredients are used in the following proportions:

Lump lime	30 pounds
Sulfur	20 pounds
Salt	15 pounds
Water	60 gallons

Put all together in a barrel or other receptacle and boil for four or five hours. If a wooden receptacle is used, steam boil. Strain through a coarse cloth to take out coarse lumps, and apply as a spray while hot.

22. RESIN SOAP (SUMMER WASH).

A resin soap for summer use may be prepared in the following proportions:

Resin	2 pounds
Caustic soda	1 pound
Tallow	1 pound

Dissolve the soda in one and one-half gallons of water; then add the resin and tallow and dissolve them also by applying a moderate degree of heat, adding water enough to make three gallons. Before using, dilute one part of the soap with sixteen parts of water.

Used for the same insects as are whale-oil soap and kerosene emulsion.

23. RESIN SOAP (WINTER WASH).

*Resin	30	pounds
Caustic Soda (70 per cent.)	9	pounds
Fish-oil	4½	pints
Water	100	gallons

Place the first three ingredients in an iron kettle and cover with five or six inches of water. Boil for an hour or two until the liquid has a dark brown color, after which the remainder of the water may be added.

Other formulæ for the preparation of resin soaps have been given, but as they are not much used, I will not take space to give them here.

24. PYRETHRUM, OR BUHACH.

This substance is a vegetable powder and is obtained by pulverizing the dried blossoms of plants of the genus Pyrethrum. It may be obtained at almost any drug store, and is peculiar in its power to kill insects while it is not poisonous to the higher animals. It may be used either wet or dry. If applied in water, use in the proportion of:

Pyrethrum	1 ounce
Water	3 gallons

If applied dry, use pure and make a very light application, or dilute with flour and apply more freely.

If thoroughly disseminated in the air of a room it will soon bring to the floor all the flies and mosquitoes therein. A good way to rid a room of flies is to make the application and close the room tightly for the night. Then in the morning sweep up the flies and burn them. If they are not destroyed in this way after being stupefied, many will finally overcome the action of the powder and live.

25. TOBACCO.

Tobacco has long been used in one way or another for the destruction of insects. Its chief use seems to be for the destruction of animal and plant lice. When slowly burnt the smoke may be utilized for the destruction of lice on plants in greenhouses or window gardens. In the form of a fine dust it is often effectual in ridding plants of flea-beetles, and in the form of dust or stems is probably the best remedy we have for woolly aphis on the roots of apple trees.

A decoction made by boiling tobacco stems in an amount of water sufficient to cover them is destructive to plant lice (Aphididæ) and to lice upon cattle. Tobacco, very finely powdered, in the form of

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* This formula and directions are copied from "*The Spraying of Plants*," by Lodeman.

snuff, may also be used dry against the same insects. It is best to first spray the insects with water.

26. SULFUR.

Everyone knows of the use of sulfur fumes for the destruction of animal life. Sulfur is specially destructive to "red spiders" and "brown mites," and may be applied as flowers of sulfur, dry, through a blow-gun of some sort, or mixed in water or soap solutions in the proportion of an ounce to a gallon of the liquid and applied as a spray.

27. HOT WATER.

Water heated to 125 to 135 degrees Far. kills very quickly any insect that is put into it, but is harmless to plants unless they are kept submerged for a long time. Lice, especially those on roots, may often be killed conveniently with hot water.

SUBSTANCES THAT KILL BY BEING INHALED.

There are two insecticides of this sort that are of special importance. As both are destructive to vegetable life also, care must be had in their use that they are not applied in strengths that will destroy the plants. It is important that tents, rooms, or other receptacles in which objects are placed for fumigation, be as nearly air tight as possible.

28. CARBON BISULFIDE; "FUMA."

This is a clear, extremely volatile liquid with a very disagreeable odor. The fumes are heavier than air, so that it is always best to expose the liquid in the upper part of a building, or other receptacle, containing objects to be treated. The fumes are explosive also when mixed with air, so that great care must be taken not to bring fire near them.

For the purpose of fumigating a building or other inclosed space containing growing plants, not over one pint of the liquid to 1,000 cubic feet of space should be used. For the destruction of insects in seeds, carpets or clothing it may be used much stronger.

To destroy ant hills, thrust a sharp stick down into the hill to a depth of eight or ten inches and then remove it and pour in two or three ounces of the carbon bisulfide; fill the hole with earth by stamping on it, and then throw over the hill a wet blanket to hold down the fumes. Allow the blanket to remain for a half hour at least, and the ants will be dead. If the hill is a very large one it would be well to make two or three holes for the carbon bisulfide.

To kill prairie dogs, pour three or four ounces of the liquid on a ball of cotton and roll the latter down the prairie dog hole and quickly fill the mouth of the hole with dirt.

For the destruction of the woolly-louse of the apple, thrust a crow-bar or other sharp instrument into the ground to the depth of one foot and at a distance of two feet from the crown of the tree and upon three sides of the tree. In each of these holes pour one ounce of the carbon bisulfide and close the holes quickly with damp earth. This is a cheap and effectual remedy and, if care is taken to have the holes made two feet from the tree and to have only about an ounce of the liquid put in a hole, there will be no danger of killing the trees.

This substance is expensive when purchased in small quantities at a drug store. It may be obtained quite cheaply if purchased in 50-pound lots, from Mr. Edward R. Taylor, Cleveland, Ohio. Write for prices.

29. HYDROCYANIC ACID GAS.

This gas has come into very general use, particularly in the orange growing sections of the country, for the destruction of scale insects. It may also be used for the destruction of insects in mills and in dwellings and in closed receptacles generally. Some of the best nursery men have adopted the plan of fumigating all their nursery stock with hydrocyanic acid gas before shipping to their customers.

The chemicals of which this gas is made are cheap and are used in the following proportions:

Potassium cyanide (of 98 per cent. purity)	1 ounce
Commercial sulfuric acid	1 ounce
Water	3 ounces

The above quantities are sufficient for a space of 100 cubic feet for the fumigation of dormant trees and plants (nursery stock). It may be used in the same strength, or even stronger, for the fumigation of mills, houses, clothing and the like.

The tent, building or receptacle in which the fumigation is to take place, should be as tight as possible. The less wind there is the better, if the fumigating room is not very tight.

The gas should be generated in an earthen jar, or wooden bucket or tub. *The chemicals must be added in the following order:* First put in the water; then add the acid; and, after the water and acid have mixed, add the potassium cyanide. A good way to add the poison is to have it tied in a paper sack and placed upon a piece of board over the dish containing the acid and water, with a string attached to the sack and passing to the outside. Then, when everything has been made tight, a pull on the string will precipitate the sack of cyanide in the acid and a rapid escape of the poisonous fumes (HCN) will immediately take place, causing violent bubbling of the liquid. Filling ones lungs with these fumes would cause almost instant death, so that great care must be taken not to breath them. Fumigating rooms must be arranged so that doors or windows of some sort can be raised from the outside quickly. Then a thorough airing must take place before anyone enters.

It would require considerable space to give full directions for the fumigation of orchard trees, and, as there is little likelihood that such fumigation will be called for in Colorado for some time to come, I shall not take space to describe the process here. Those specially interested can obtain bulletins giving full directions from the Department of Agriculture, Division of Entomology, Washington, D. C. Full directions can also be obtained in a book entitled "Fumigation Methods," by W. G. Johnson, and published by Orange Judd Co., New York. Figs. 16 and 17 are from this book.

SUBSTANCES THAT REPEL.

There are a number of substances that are more or less useful for the purpose of driving insects away from places where they would do harm if unmolested. I give below a few of the most important.

30. NAPTHALINE, GUM-CAMPHOR, AND MOTH BALLS.

Napthaline crystals are much used in insect boxes and in boxes or trunks where furs, feathers or woolen goods are kept, for the purpose of keeping out insects that feed on these animal products. It is probably the best single chemical that can be used for this purpose. Gum-camphor is also much used for the same purpose and moth-balls are a combination of these two volatile substances. These materials cannot be used to kill insects, but only to repel them.

31. TOBACCO.

Tobacco, in the form of dust, or otherwise, is often used for the same purpose as the preceding, but to be effectual must be used quite freely.

32. ASHES.

Ashes, particularly from wood, are frequently used to dust upon plants after a rain or while the dew is on and often result in the insects disappearing. Particularly is this true in case of flea-beetles and the cucumber beetle when feeding upon leaves. Ashes do not kill the insects, but they make the food distasteful, so the insects are driven to other plants.

33. LIME, PLASTER, AND ROAD DUST.

These substances are also used like ashes as repellents, but are of little or no use for the destruction of insects.

INSECT TRAPS.

There are many methods of trapping and destroying insects. One of the most common is the use of bright lights exposed at night.

34. LIGHTS.

The usual plan is to place a light over a dish of some sort that contains water with coal oil on top of it. Many night-flying insects are attracted by lights and may be destroyed by devises of this kind, but there are also many insects that fly at night that are not attracted by lights. Such an insect is the codling moth, though light traps are often recommended for its destruction. Among those insects that are readily attracted by lights might be mentioned the adults of the army worm, of the various cut-worms, the garden web-worms and the corn or boll-worm.

It is not infrequently the case that more of the beneficial insects are destroyed than of destructive species, and it is quite doubtful if lights are often of any considerable importance as a means of lessening the injury to crops by the destruction of insects.

35. SWEETENED WATER, CIDER, VINEGAR, ETC.

Some insects are attracted in considerable numbers to such substances as the above, but it is very seldom that the benefit derived from them will pay for the trouble and expense of using them. Mr. David Brothers, of Edgewater, Colo., reported excellent success capturing moths of the fruit-tree leaf-roller with weakened vinegar in pans in the orchard, and the codling moth is attracted to some extent to a mixture of molasses and vinegar placed in apple trees. The advantage of such baits for the capture of insects is usually greatly overestimated by those who use them.

36. BANDAGES.

Heavy cloth or paper bands placed about the trunks of apple trees are quite useful for the capture of the larvæ of the codling moth that are leaving the apples and going in search of a suitable place to spin their cocoons. Burlap bands are cheap and seem to be as good as any. The writer took 1,481 codling moth larvæ under a single burlap band one season. Old gunny sacks cut into strips serve as well as anything. The band should be not less than four inches wide and should be composed of three thicknesses of the cloth.

The bands should be wrapped loosely about the trunks, the ends overlapped and held in place by a single carpet tack pushed in with the thumb.

If used against the codling moth they should be removed once in a week or ten days for the purpose of killing all the worms and then replaced.

The bands should be placed on the trees about the 10th of June in the warmer parts of the State, and about the 25th of June in the northern parts.

Heavy paper may be used in place of the cloths.

The peach twig-borer can also be taken under these bands.

Bands of paper or wire screen are sometimes wrapped about the entire trunk to prevent the entrance of borers, as shown in Plate IV., Figs. 2 and 3.

37. HOPPER-DOZERS OR HOPPER-PANS.

For the purpose of catching jumping insects, especially grasshoppers, the hopper-dozer or hopper-pan is most useful. There are different methods of constructing these pans. A form used by Dr. Riley and illustrated by him many years ago is shown at Fig. 2. The pan in the illustration is entirely of sheet-iron, and is drawn across the fields by two men or two horses. In the bottom of the pan is placed a small amount of water with kerosene on top of it. All grasshoppers that come in contact with the oil die. The back of the pan may be extended by means of stakes at the corners and a strip of cloth hung between them. Such an extension catches many grasshoppers that would otherwise escape.

38. STICKY SUBSTANCES.

Bandages of sticky substances, such as printer's ink, "Dendroline," or "Raupenleim," or even cotton batting, are sometimes used to prevent insects from climbing trees. Where oily substances are used it is safer to put them on a bandage of stout paper, which is then wrapped about the trunk of the tree.

THE APPLICATION OF INSECTICIDES.

IN THE DRY WAY.

The upper surface of the leaves of all low plants can be easily treated with a dry insecticide by dusting it upon them through a cheesecloth, or other thin muslin sack, held in the hand. There are also various appliances upon the market for the distribution of powders. One of these that is very convenient for filling the air of a room with dust to kill flies, or for the application of powders to low herbage, is shown in Fig. 15. It can be had of Thomas Woodason, 451 East Cambria Street, Philadelphia, Pa.

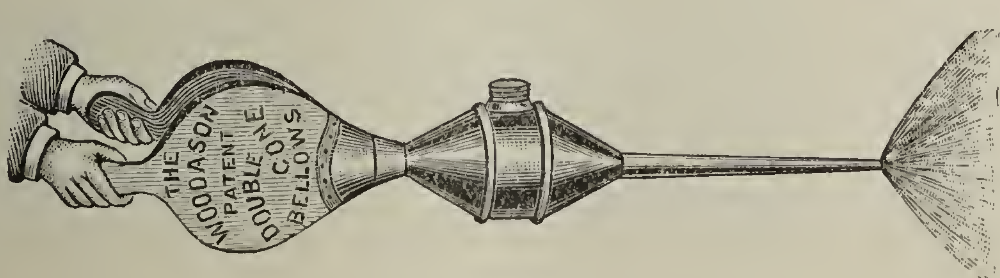

FIG. 15.—Dust-sprayer.

The Hillis Dust Sprayer Co., St. Louis, Mo., manufacture a

"dust-sprayer" large enough to distribute dry insecticides through trees of the size of an ordinary apple tree.

IN THE WET WAY.

There are so many manufacturers of spray pumps and nozzles of all descriptions that it is impossible to point out any make as being the best. The illustrations here given are for the purpose of giving the reader an idea of the kind of a pump that will be needed for his work. Each must be his own judge as to the quality and price of the pumps offered him.

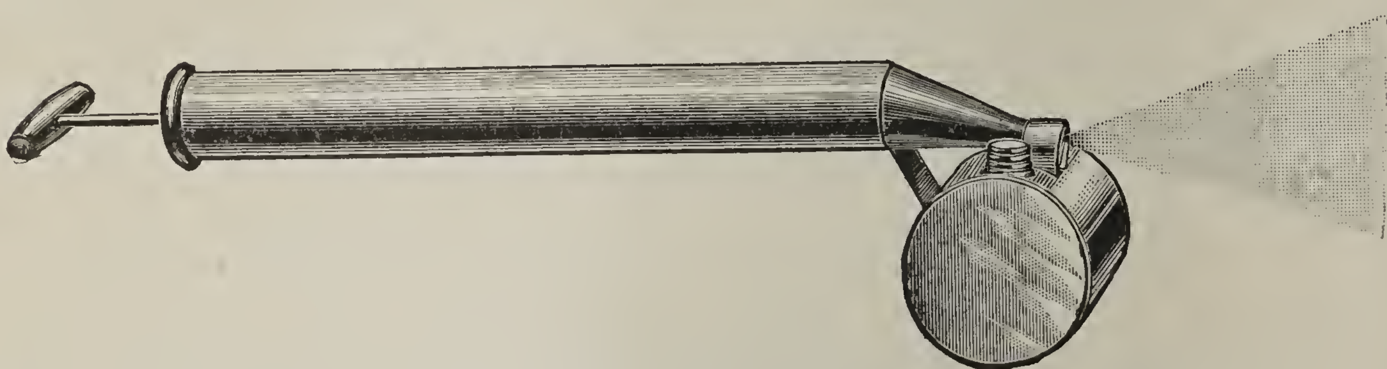

FIG. 16.—"Faultless" Hand Atomizer.

Fig. 16 is an illustration of the "Faultless Sprayer, manufactured by F. E. Myers & Bro., Ashland, Ohio. It is inexpensive and will answer well where only a few small plants are to be treated.

FIG. 17.—Bellows Atomizer.

Fig. 17 shows a form of atomizer, having a similar use, also sold by Woodason, of Philadelphia.

PUMPS.

Pumps with metal valves should be obtained for the application of insecticides or fungicides in liquid form, as the materials used harden or decompose leather valves so that they last but a short time. If the pump is to be used with a tank or barrel it is also important to have some kind of attachment that will keep the liquid agitated so the materials in suspension will not settle. A common error is to purchase a pump of too small capacity, because it is cheaper. A smaller, cheaper pump usually means less accomplished in a day with the same help, but with a greater expenditure

of energy. And then, it is often important to complete the spraying in as short a time as possible after it is begun. To do this, a pump of large capacity with two or more leads of hose is necessary. The hose to which the nozzles are attached should be as light as possible and still have the requisite strength—a hose of good quality with heavy wall, but small caliber. Fig. 18 illustrates a form of bucket pump manufactured by The Deming Company, Salem, Ohio. Bucket pumps are sold by different dealers at prices ranging between about $2.00 and $8.00 in price. They are suitable for use among vegetables, shrubbery and all low plants, but should not be purchased for orchard work if one has more than a very few trees to treat. In the small sprayer shown at Figure 19 the liquid is forced up by means of air pressure. Such a pump is often convenient when a person is compelled to do his spraying alone. This sprayer also has an oil attachment, so that water and kerosene may be applied mixed without the trouble of making an emulsion. This pump is manufactured by Leggett & Brother, New York City.

FIG. 18.—Bucket Pump.

FIG. 19.—Leggett's Air-pressure Pump.

Fig. 20 shows a form of air-pressure sprayer sold by the North Jersey Nurseries, Springfield, N. J.

Many prefer some form of the knapsack sprayer for the treatment of low plants. At Fig. 21 is shown one of these sprayers as sold by William Stahl, Quincy, Ill. Knapsack sprayers are also

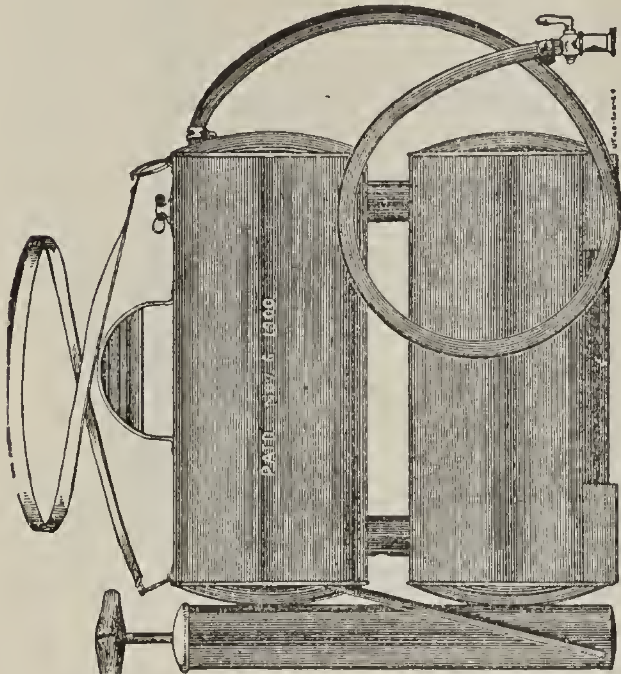

FIG. 20.—Another form of Air-pressure Pump.

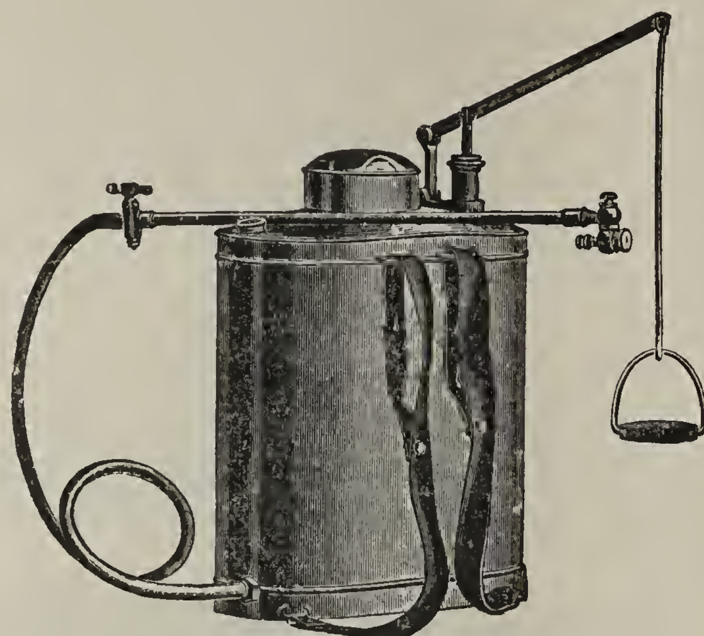

FIG. 21.—Knapsack Sprayer.

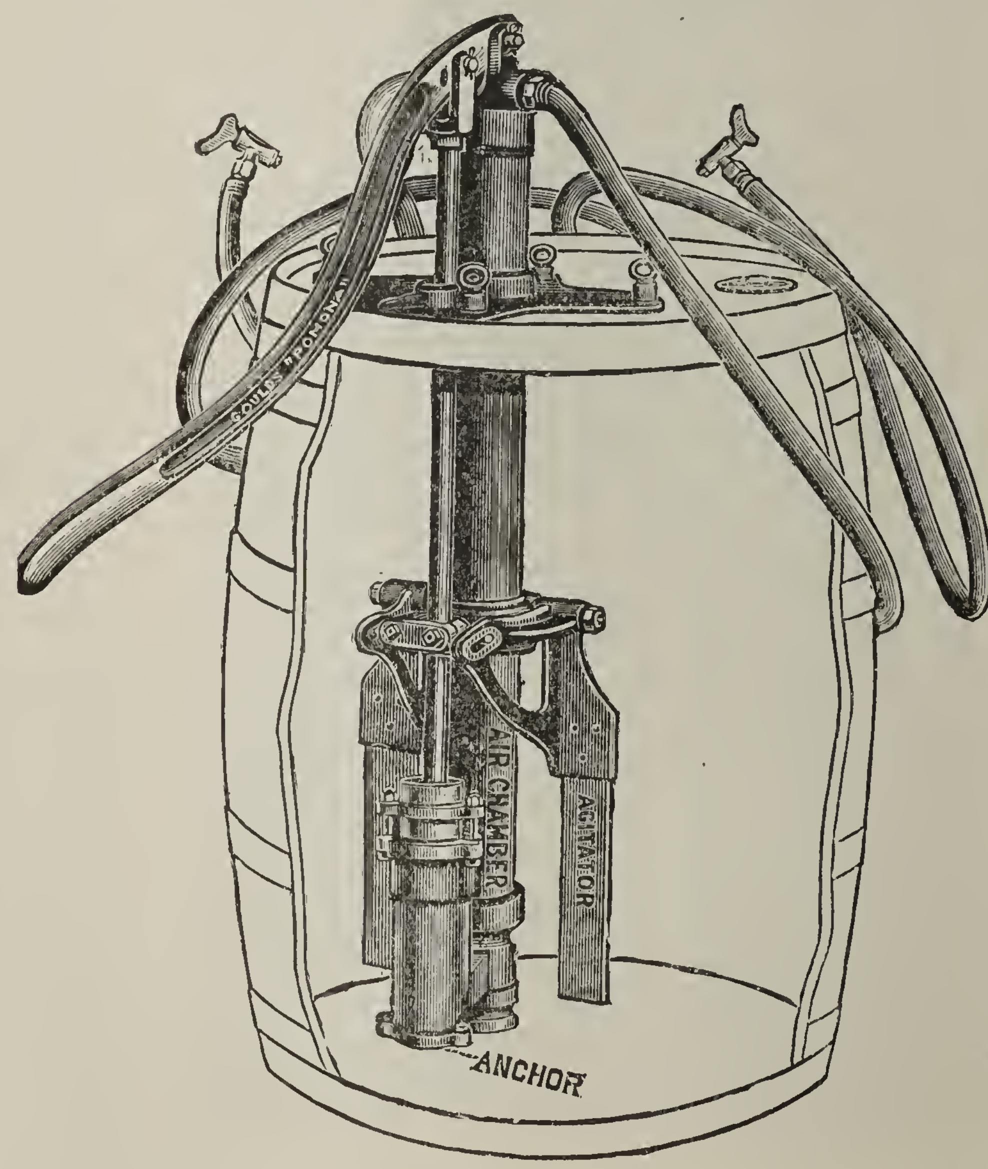

FIG. 22.—Barrel Pump.

made with an oil tank attached so as to spray kerosene, or petro-

leum, in a mechanical mixture along with water, so as to do away with the need of making an emulsion.

For the treatment of small orchards a barrel pump is generally used. One of the best of these is Gould's "Pomona" spray pump shown in Fig. 22. The pump carries two leads of hose and has a patent agitating arrangement within the barrel. It is sold by The Gould Manufacturing Co., Seneca Falls, N. Y.

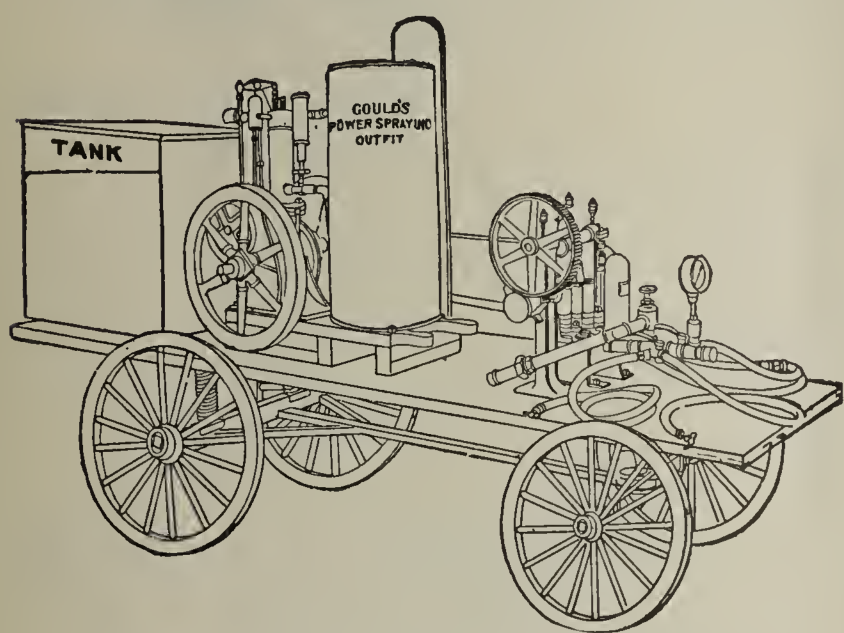

FIG. 23.—Power Pump. Run by Gasoline Engine.

Where a large amount of orchard spraying is to be done larger pumps and tanks should be used. Fig. 23 shows a gasoline power sprayer attached to a large wagon tank. Such sprayers will easily run four leads of hose and keep up a high pressure. Without a good pressure it is impossible to throw a fine and forcible spray. The power sprayer here shown is also manufactured by The Gould Manufacturing Co. There are many other companies manufacturing spraying apparatus. Their advertisements will be found in agricultural papers. If anyone is thinking of purchasing an expensive spraying outfit he should obtain catalogues and prices from several manufacturers or dealers and then purchase where he thinks he can do best.

HOW TO SPRAY.

The first requisite for a good job of spraying is a pump that will give plenty of pressure in the hose. Then, if one has a good spraying nozzle and a liquid that is free from solid particles of a size to clog the sprayer, there will be no difficulty in getting a good spray. A very fine spray is most economical of material and, for an even and thorough distribution, is best. Care should be taken, also, not to continue the spraying until the little drops that collect on the foliage unite and run off, carrying the poison with them. In some cases, however, as when spraying the first and second times for the codling moth, the writer prefers a rather coarse spray and to continue until the calyces of the forming fruits have all been thoroughly drenched without regard as to how much the liquid is dripping from the foliage. The medium coarse spray is preferred for this work, because the larger drops carry better into the blossoms, or calyces, of the apples.

The "Seneca" nozzle sold by the Gould Manufacturing Co. and shown at Fig. 24 throws a good coarse spray. The "Bordeaux"

nozzle shown at Fig. 25 and sold by The Deming Co. is one of the

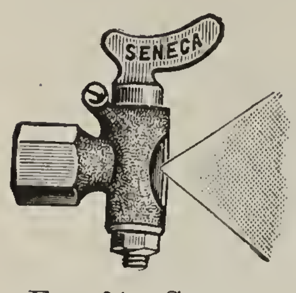

FIG. 24.—Seneca Nozzle.

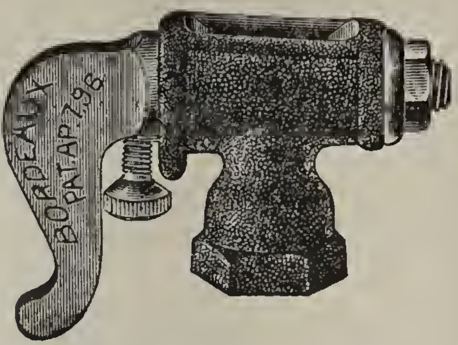

FIG. 25.—Bordeaux Nozzle.

best nozzles for either coarse or medium fine spray. For a very fine, misty spray I know no nozzle that equals the "Vermorel." This nozzle is mounted singly, as shown in Fig. 26, or in batteries of two, three or four nozzles combined. A battery of two nozzles is shown at Fig. 27. Figs. 26 and 27 are from the catalogue issued by the Gould Manufacturing Co.

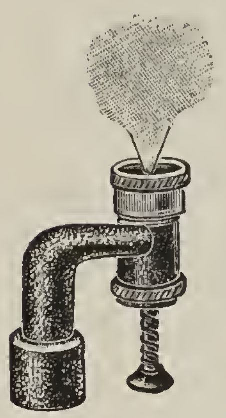

FIG. 26.—Single Vermorel Nozzle.

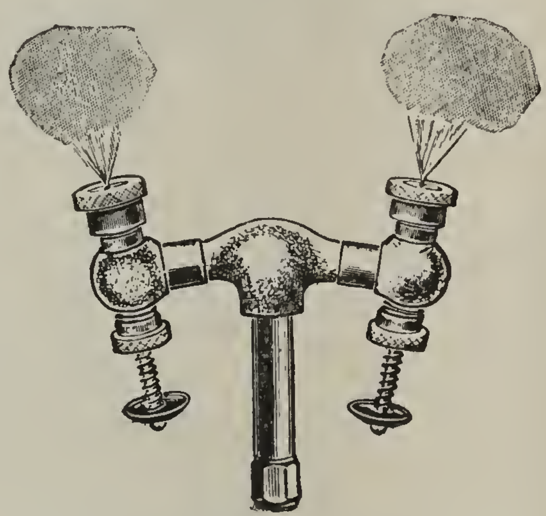

FIG. 27.—A Battery of two Vermorel Nozzles.

For farther information in regard to insects or insecticides address the Experiment Station. When making inquiries concerning insects, send samples of the insects and their injuries whenever possible.

Bulletin 72. **August, 1902.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

A Soil Study.

PART IV.

THE GROUND WATER.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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A Soil Study:

Part IV. The Ground Water.

By WILLIAM P. HEADDEN, A. M., Ph. D.

§ 1. I have presented the results of our experiments and observations upon the effects of alkaline conditions of the soil upon crops, upon the sugar beet in particular, in Bulletins 46 and 58, forming Parts I and II of this study. In Part III, Station Bulletin 65, I have presented the subject of the soil, and the effects of cultivation upon it, from both the chemical and physical standpoint. The conclusions reached in these bulletins have been summarized in the respective publications and will not be reproduced in this place, as reference can easily be made to the statements of them in the originals, which are fuller than could be made here.

SOME OBSERVATIONS ON ALKALIZATION.

§ 2. The statement made on page 3 of Bulletin 46, relative to the general question of alkalization in Colorado is, I believe, correct. I would state the question even more explicitly, especially for the eastern slope of the Rocky Mountains, for I am convinced *that the only question of alkali that we have resolves itself into one of drainage, and beyond this, there is no alkali question for us.* I believe this to be true of the western as well as of the eastern portion of the State.

§ 3. I am aware of the fact that some sections of the State have an abundant supply of alkali salts, but their presence and whatever injurious effects they may have produced, is due principally, if not wholly, to the lack of drainage, which, in many instances, has been made more apparent and its effects greatly augmented by over-irrigation. An immoderate use of water, especially when no regard is had for drainage, the peculiarities of the soil or the requirements of the plants, can prove as disastrous to the agriculture of a section as other naturally adverse conditions. This cause of trouble will be lessened in all parts of the State as the de-

mand for water approaches the limit of the supply and an economic and intelligent use of it is forced upon the agriculturists. As an illustration I may give the following facts which were stated to me—not for the purpose for which they are here used—by a person conversant with them: In a certain section of the State the water table was about 18 feet below the surface and the water was usable, though not good. A few years after the irrigating ditch, which furnished a super-abundance of water, had been built, the water plane had raised by 15 feet or more, with the result that the depressed portions of the country were being drowned out. The water, which had become heavily laden with the alkalies, was much less desirable than formerly, or wholly unfit for use. The people, as a matter of course, did not take it kindly when the writer insisted that there were two contributing causes to this state of affairs, over-irrigation and lack of drainage, and that the remedies were simple if feasible. The first was to apply less water, which could easily be done; the second, to drain the land, which could not easily be done.

§ 4. The character of the underlying strata, the presence or absence of a hard pan, often contributes to bringing about bad drainage conditions, but this was not the case in the above instance, and I think that it is not very generally the cause in any section of this State. I have seen no occurrence of alkalies in this State where their accumulation was not due to these causes, usually to the lack of drainage, the alkalies accumulating in depressions with no outlet which serve as collecting places for the water running off of or draining from the higher ground, or along water courses where the lowness of the land and character of the vegetation prevent proper drainage.

THE CONDITIONS OF THE PLOT EXPERIMENTED ON.

§ 5. The plot of ground chosen for our experiment was in the worst condition of any plot at our disposal. It was quite wet, had no hard pan, but a stratum of clay at a depth of about 5 feet, underlain by gravel. It was not drained, though a tile drain had been laid to the west, south and east of it, but at so great a distance that it failed to perceptibly affect the condition of this plot. An irrigating ditch flows within 50 feet of the east end of the plot, and one perhaps 150 feet from the west end of it, both being at a higher level than the plot itself, which has a slope to the eastward of six inches in a hundred feet. The ditch passing the east end of the plot was, we feared, an important factor. We will subsequently state the results of our observations made to determine to what extent this ditch influenced the water level of the plot.

§ 6. Such were the general conditions of the ground chosen

to experiment on, and which was chosen as representative of much land in Colorado which is neither so wet as to be untillable nor so strongly alkalized as to be hopeless, and yet was strongly enough impregnated with salts to yield, under favorable conditions, incrustations reaching a half inch in thickness.

§ 7. Parts I and II of this study deal exclusively with the effects of these conditions on the growth and composition of sugar beets, the crop chosen to grow on this land, because we thought it probably more tolerant of the conditions than any other crop which would at the same time serve the other purposes of our study.

§ 8. Part III deals with the soil, giving an account of the mechanical and chemical effects resulting from our cultivating and manuring it. In this bulletin, Part IV of our study, we shall present the results of our observations on the ground water, the changes in the water used for the purpose of irrigating, the salts removed, etc. I shall confine myself in this bulletin to the subject of water, as in Part III I confined myself to the subject of the soil.

§ 9. I have stated the general condition of the plot at the beginning of the experiments; I have stated the reasons which induced us to choose this plot of ground as well as the crops to be grown thereon; and in Part III I have given the condition of the soil at the end of our experiments, which is summed up by stating that the store of plant food in the surface soil, taken to a depth of ten inches, was actually increased. This, however, was the lesser part of the improvement, the greater part lay in the betterment of the general conditions, whose best features cannot be shown by chemical analysis or expressed in any formula. The strongest and most interesting point in this connection is that the conditions of water supply and drainage have remained the same throughout the experiment. The ground has subsequently been drained, in part, at least.

§ 10. The amount of water in the soil was not determined for the reason that the soil was excessively wet, the water table being at times within a few inches of the surface, and in parts of the plot, seldom more than three feet six inches below it, while in the highest portion of the plot it was only six feet from the surface at its lowest stage. One would think that, under such conditions, irrigation would not be needed; that the sub-irrigation would be sufficient. We did not find this to be the case. The explanation probably lay in the fact that the root system accommodated its development to the conditions obtaining during the earlier and greater portion of the season, and when the water table fell the surface soil, owing largely to its unfavorable mechanical condition, dried out rapidly to a greater depth than a soil in good mechanical

condition would have done, causing the plants to suffer. The plant, too, may have become more sensitive to a lack of water, owing to the usually large supply of it. Whether this is the explanation or not, we had to irrigate two out of three seasons, and while we irrigated the third season also, it was probably not actually necessary so far as the growing of the beets was concerned.

§ 11. The height of the water table in the plot was referred to a plane 10 feet below our bench mark. The wells were designated as A, B, C, D, E, F, G and H; their respective heights, referred to the same plane, were: A, 9.41′; B, 11.12′; C, 11.23′; D, 12.71′; E, 7.24′; G, 9.59′. The heights of F and H were not determined; these wells were dug for special purposes, which it would be out of place to explain at this time. Wells A, B, C and D were the principal ones and were dug at intervals along the central line of the plot, which had a width of 50 feet and a length of 600 feet. The distances between the wells were not equal. Well A was the most easterly one, and was 130½ feet from the center of the ditch; B was 150 feet west of A; C 175 feet west of B, and D 160 feet west of C. The surface of the plot at D is 3.3 feet higher than at A; the surface of the underground water is 1.83 feet higher. The distance from A to D is 485 feet, accordingly the surface of the water table has a fall of 1.83 feet in 485 feet, while the surface of the plot has a fall of nearly twice as much. The greater height of the water table at the west end is probably due to the friction of the flow, and is but little modified by the contour of the surface.

§ 12. I suppose that the escape of the ground water is to the eastward, though I have no direct proof of this. There is a drain running from a depression west of the plot, making a wide curve and passing again to the east of it. This drain was put in in this shape to cut off seepage from higher lying land to the westward and to drain a still lower lying portion to the east of the plot. I have elsewhere stated that it accomplished its purpose but partially.

§ 13. The daily records of the height of the water plane show that it varied quite uniformly throughout the plot—the wells as a rule rising and falling together. At times there would be a rise in the water table when no rainfall had taken place and no land had been irrigated which could affect the height of the water plane in this plot. Such rises in the water plane were probably due to meteorological conditions. A rainfall of a fraction of an inch also affected it, owing to the nearness of the plane to the surface, by modifying the capillary force within the soil. A rainfall of 0.28 of an inch at 4:30 on the 8th of July was followed on the 9th by a rise of from 0.74 to 0.90 of a foot in the water level; but a rainfall of 0.9 of an inch on the night of the 9th produced a mixed result,

which was probably due to the varying character of the soil and the air contained in it. On the night of July 18th a rainfall of 0.21 of an inch occurred, and the water plane on the morning of the 19th had risen rather more than 0.40 of a foot as an average for the four wells. No further rainfall occurred, and the weather conditions remained favorable for observing how long the effect of such a rainfall would remain noticeable. On the morning of the 20th the level had fallen about 0.2 of a foot, and by the morning of the 22d it had attained the same level that it had on the 18th, prior to the rainfall. On the 23d it was a little lower, but rose again on the 24th.

§ 14. The height of the water plane oscillated throughout the season, owing to the causes already mentioned, and was also influenced directly by irrigation of higher lying land. The record for 1898 was a weekly instead of a daily one, and the minor changes due to meteorological causes were largely eliminated, and only the larger ones, such as were caused by drainage, or continued meteorological conditions, are shown.

§ 15. There was a rise of the water table throughout the plot during the month of February, 1898, of about 0.5 of a foot. The total rainfall was only .08 of an inch. During the month of March there was a fall in the water level. There was a greater rainfall than in February, though it was still insignificant. This oscillation was a longer one than is due to the usual meteorological influences or to irrigation, besides no irrigation was being practiced at this season. It may have been due to freezing and thawing and to the consequent change in the freedom of the circulation of either the water or the air within the soil.

§ 16. I supposed that the presence of the irrigation ditch near the east end of the plot exercised some influence upon the height of the water level in its immediate neighborhood. In order to observe the extent of this, the height of the water in two wells, A and G, was observed before water was turned into the ditch in the spring, and when no water had run in it for several months. We made no effort to determine whether its influence was by leakage or otherwise. The wells taken under observation were close together, A entering the gravel below the clay, while G did not reach the stratum of clay mentioned as separating the soil from the gravel, and was presumably supplied with water from the soil proper. Well G was not so deep as well A by 2 feet. The distance between the wells was 12 feet. The water in well G usually stood a little higher than in well A, whether there was water in the ditch or not. It should be added, for a better understanding of the conditions, that the ground on the east side of the ditch sloped gently to the eastward and lay between the ditch and the drain

already mentioned. Water was turned into the ditch late in the afternoon of April 20th. By 6:15 p. m. of the 23d the water plane had risen 0.31 of a foot in well A, and 0.30 of a foot in well G, the former being $130\frac{1}{2}$ feet and the latter $142\frac{1}{2}$ feet distant from and west of the ditch. No rain had fallen during the preceding 17 days, and the effect observed was probably wholly due to the influence of the ditch, and it is doubtful whether the effect of the ditch upon the height of the water plane was ever much greater than is here indicated, 0.30 of a foot.

§ 17. The total solids and the chlorin present in the water before and after the rise showed a decrease. If the rise were due to unfiltered water passing in from the surface, or even near it, as from the bottom of the ditch, this result would stand alone and in contradiction to the results observed when the level of the water had been raised by a copious rainfall or by the application of irrigation water. In both of these cases the total solids and the chlorin were greatly increased, but not in any definite ratio—the increase in the amount of chlorin being more rapid than that of the total solids.

§ 18. The decrease in the total solids held in solution suggests the damming back of the underground water and a rising of water which was usually below the clayey stratum. The principal fact on which this interpretation rests is that the water taken from below this stratum was actually poorer in total solids than the water above it. We also attempted to study the effect of a drain run for the most part just outside of and south of the plot, but owing to a variety of causes, the principal one of which was our inability to properly attend to it, this experiment was abandoned.

§ 19. When the water table in this plot had been raised by irrigation it required from 10 to 13 days for it to fall to the level at which it stood before irrigation. The rate at which it fell was very nearly the same throughout the plot and did not reach this level at the west or higher end first and gradually proceed eastward as it would do if there were sufficient freedom of flow and the drainage was from the east end of the plot.

§ 20. It is mentioned on a preceding page that when the water level rose owing to the change in the conditions of capillarity caused by a slight rainfall, it required only about three days for it to recede to its former level, while we state that after an irrigation it required from 10 to 13 days. The two cases are quite different. In the latter case we have displaced the air and filled the soil with water, piling it up on the existing water plane; in the for-

mer we pulled it up by a force which gradually lost its power and permitted it to subside.

§ 21. The general observations on the water level in this plot shows that it is subject to small oscillations due to meteorological conditions, and that there are also oscillations extending over several weeks, the cause of which we have not attempted to suggest, and in addition to these, the accidental ones caused by rainfall or irrigation.

§ 22. The water table in the east end of the plot was seldom at a depth exceeding the height to which water would be raised by the force of capillarity, and in this section the accumulation of alkali was the greatest. This plot gave us throughout its whole extent a good opportunity to study the changes in the character and quantities of salts in the ground water.

TOTAL SOLIDS IN THE GROUND WATER.

§ 23. Samples of the ground water were taken weekly for the determination of the total solids. There seemed to be no relation between the different wells in this respect, their content being determined by the conditions obtaining in their immediate vicinity. For instance, well A, situated in the worst portion of the plot, carried on May 24th 3.6114 parts per thousand; * this quantity fell, with slight fluctuations from week to week till the end of June, when it carried 2.8714 parts. Well B, which was 150 feet west of A, carried at the beginning of this period 2.7843 parts per thousand, which rose to 3.2828 parts by June 21st, and fell to 2.9143 parts by the 28th. Well C carried, May 21st, 2.5000 parts per thousand, on June 28th 2.3286 parts. The changes in the total solids present in well D were almost identical with those observed in the case of well C. The rainfall during this time amounted to 2.08 inches. The height of the water table had varied during this period, but it was almost exactly the same at the end of it as at the beginning, the greatest variation being 0.1 of a foot higher.

§ 24. The cause of this gradual fall of the total solids held in solution by the ground water was probably not due to the influx of ground water from the west carrying a less quantity of salts in solution, for subsequent examination showed that the ground water from this direction, some of which, at least at times, found its way into this ground, was richer in this respect than the ground water usually filling this soil. The above statement that some of this water from the west found its way into the plot merely means that in extreme cases the level of the water table in the plot was affected by

* To convert parts per thousand into grains per U. S. gallon, multiply by 58.334946, into grains per Imperial gallon by 70.0.

it, and not that I assert the actual flowing of this water to the eastward through the plot, for the total lack of agreement in the amount of the total solids in the water of the different wells, there being only an approximate agreement when the wells were only 12 feet from one another, indicates that the change of level was an actual rising and falling due to changes in pressure, mostly hydrostatic, rather than to a flowing in and mixing of other waters. If such took place above the water plane, we should expect to observe effects similar to those produced by the entrance of water from above as in the case of heavy rainfalls or irrigation.

§ 25. I have not been able to detect any pushing along of the water, indicated by the amount of total solids in solution, nor yet by their composition. I thought to test this by the addition of a quantity of a lithium salt into one of the wells, but this experiment was a failure for reasons hereafter given.

§ 26. The water soluble in the soil at various depths with high and low water plane, was not determined, but it is probable that the diminution of the total solids in solution was due to the removal of the salts from the solution and deposition of the salts in the upper portions of the soil. The organic matter held in solution fell with the total solids, judging by the loss on ignition, allowance being made for water which may have been present in gypsum.

§ 27. The irrigation applied on June 29th was not a copious one, because we had only a small quantity of water at our disposal. Its effect on the height of the water plane did not reach its maximum for several days. It was followed by an increase in the total solids in the water, but this was so irregular in its amount and in the time of its appearance that it is difficult to give an exact statement of it beyond the general one that an increase followed it. On the day previous to the application of irrigation water, the total solids in the water of well A were 2.8714 parts per thousand; five days later it carried 3.6871 parts, and twelve days after irrigation it reached 4.4443 parts. This quantity gradually decreased until just before the next irrigation it had fallen to 2.5900 parts per thousand.

§ 28. There was only a general similarity in the deportment of the wells, the individuality of the separate wells being very marked. In well B, for example, the total solids present just before irrigation amounted to 2.9143 parts per thousand, which rose to 3.1000 parts, fell to 3.0000 parts, and then rose continuously for the next eight weeks while they were falling in the other wells. The subsequent, second irrigation caused an increase in the total solids in the water of all the wells, but it was very much less in

that of well B than in that of wells A and C on either side of it. This was not influenced by the height of the wells, for A was 0.70 of a foot lower, and C 0.77 of a foot higher than B. This irrigation caused an increase of 1.2286 parts per thousand in the solids in A, 2.7714 parts in that of C, and rather less than 0.0428 parts in that of B. In the case of well D there was an actual depression of the solids by 0.0714 parts per thousand, but this was probably due to the running in of water from the surface. The subsequent deportment of this well was similar to that of well B.

§ 29. The total solids in wells A and C increased suddenly after the irrigation and then fell again, reaching the point at which they stood prior to the irrigation in about three weeks. In wells D and B the total solids increased throughout this period, at the end of which the water in B showed its maximum content for the season, 4.2143 parts per thousand; in D, however, they continued to increase for three weeks longer before reaching their maximum for the season of 3.6986 parts. The maximum quantity of salts in solution in the water of well A was reached immediately after the irrigations, 3.7857 and 3.8143 parts per thousand respectively; the minimum was found in September, 2.7871 parts per thousand; in B the minimum was found in May and the maximum in September, more than three weeks after the irrigation. In C the minimum was found in June, immediately before irrigation, and the maximum, 5.1929 parts per thousand, in August, immediately after irrigation. In D the minimum was found in June and the maximum in October, over six weeks after the last irrigation. From October, 1897, till May, 1898, the total solids in the water gradually decreased, with only a few increases which were slight and immediately lost. The net result at the end of the year was a very slight decrease in the salts held in solution by the ground water. The wells showed the following quantities of salts in solution at the beginning and end of the year respectively: A, 3.6114—2.8714 parts per thousand; B, 2.7843—2.8328 parts per thousand; C, 2.5143—2.0329 parts per thousand; and D, 2.5700—2.0843 parts per thousand.

§ 30. The deportment of well B is not such as one would expect to observe in it judging from its location. Wells A and C were located in wetter and apparently more strongly alkalized sections than well B, and the sample of the soil taken near B showed the presence of less sulfuric acid and soda than those from near the other two wells, yet the water from this well is richer in dissolved salts throughout the year than the others, excepting that of well A for the month of May alone.

§ 31. When the height of the water plane is raised by irrigation water, or a continued rainfall, the percolating water carries the

soluble salts with it into the ground water, and an increase in the salts dissolved in the ground water is simultaneous with the rise of the water table. It is evident that this rise is due to the piling up of water on a portion of the general water plane represented by the irrigated plot, and would not take place if the water could flow perfectly freely through the soil, which it does not do. This does not fully state the facts in regard to the increase and decrease of the salts in the ground water; for while it is true that there is an increase in the salts concurrent with the rise of the water table when it is due to the application of water to the surface, and a subsequent fall, usually quite a rapid one, we have the solids in the water of two of the wells showing a different course. The solids in that of wells B and D began to increase immediately, or very soon, after the irrigation of August 18th to 20th, and continued to increase for several weeks, though the water table was steadily falling during this time, which in the case of well D was six weeks. This is the more remarkable for in both these cases the maximum reached was the maximum for the season. In the case of the other two wells the results were in the opposite direction. In the waters of these wells the amount of the dissolved salts reached their maximum for the season immediately after the irrigation and fell within four weeks to their minimum for the remaining months of the year, and within 0.1571 parts per thousand of the minimum for the whole season. The cause of this difference is not suggested by a consideration of the rate at which the water table fell. The height of the water table above the reference plane was not the same in the different wells, and there were slight variations in the rate of fall, but neglecting these irregularities, the rate of falling was very nearly the same, so that the rapid decrease in the amount of the total solids in the water of wells A and C was not probably due to any drainage, affecting these wells to a greater extent or in a different manner than it did the wells B and D. The conditions of diffusion obtaining in the different wells probably contributed to the observed results. The composition of the solids contained in these waters will be given subsequently.

§ 32. In this irrigation, as well as in the preceding, the head of water at our disposal would not permit of our attempting to flood off any salts, and practically all the salts which were on the surface at any given place were carried back into the soil, so that there was but little, if any, transporting of salts even for a few feet in the direction of the flow of the water. It follows that any removal of salts during this season was by drainage.

§ 33. In the following season, 1898, the conditions were quite different. During April, and especially during May, there were frequent light rains. The water table was rather higher at the west

end of the plot and lower at the east end than in 1897. The average height of the water table at the west end of the plot for May, 1897, was 9.80 feet, and for the same month in 1898 it was 9.98 feet for the east end; for May, 1897, it was 8.11, and for May, 1898, 7.55 feet. The rainfall in the two years differed both in its amount and distribution; there was also another changed condition, the plot had been divided into sections 100 feet long by 25 feet wide, and the alternate sections had received a heavy dressing of manure. These conditions undoubtedly had an effect upon the movement of the soluble salts in the soil and also upon the salts themselves.

§ 34. There was a remarkable change in the amount of the total solids contained in the waters of wells A and C between May 16th and 23d, each containing less by 14.3 parts per thousand on the later date. The waters of the wells contained from 3.57 to 5.71 parts per thousand more total solids on May 24, 1898, than on this date in 1897, except in the case of well D, the water of which contained 3.43 parts per thousand less.

§ 35. An examination of the results obtained in 1898 corroborate those of 1897, *i. e.*, that as a rule, the solids in the waters fell as the water table fell, and that a sufficient rainfall or an application of water to the surface was followed by an increase in the amount of salts held in solution by the ground water.

§ 36. The amount of water necessary to raise the height of the water table and at the same time produce an increase in the amount of the salts in the ground water was not observed. I have already stated that a rainfall of a few tenths of an inch was followed by a disproportionate rise in the height of the water table. In the particular instances referred to we unfortunately made no determination of the total solids immediately before and after the change of the water level.

§ 37. In May, 1898, there were nine days on which no rain fell. The aggregate rainfall for the 3d, 4th and 5th was 1.66 inches, this was followed by a rise in the height of the water table, and though there were daily light rains, except on the 10th, until the 16th the water table fell by 0.2 of a foot. In this interval 0.69 of an inch of rain had fallen, 0.22 and 0.24 of an inch being the largest amounts for any one day, an amount which under other conditions had been sufficient to cause a rise.

§ 38. The total solids present in the waters of wells A and C were very high at this date, the 16th, containing 6.1043 and 4.3414 parts per thousand respectively, while those of wells B and D were much lower, 2.9000 and 2.1000 respectively; but seven days later they had fallen in wells A and C and risen in wells

B and D. A little rain had fallen during the week, and the wells, A excepted, were lower than on the 16th.

§ 39. On June 3rd, 4th and 5th we had a rainfall aggregating 1.82 inches, which under the conditions prevailing at that time might have wet this soil to a depth of 5 inches. The water capacity of this soil, air dry, ranged from 36 to 51 per cent. The actually observed rise in the water table ranged from 0.32 to 0.95 of a foot, and the waters of the different wells showed an increase in the total solids present. The increase in the case of well B was slower than in the others. The greatest difference was shown in the case of Well C, where it amounted to 1.0630 parts per thousand. The water table and the total solids had both begun to fall by the 13th, or seven days after the last rainfall.

§ 40. The rising of the water table at times when there had been no rainfall has already been mentioned, as has also the effect of a slight moistening of the previously dry surface upon the height of the water table, but here we have the effect of 1.82 inches of rainfall upon the height of the water table reaching the considerable amount of 0.95 of a foot, or 11.4 inches, while the amount of water which fell was not sufficient to wet this soil for more than 5 inches. The amount of the rise in the different wells varied considerably, as did the increase of the total solids. The former is probably due to the capillary condition of the soil at the different places, and the latter, partly to the solution of salts out of the soil through which the water rose and partly to changes in the conditions of diffusion, for the smallest change in the amount of total solids was not in the well that rose the least, nor in one which was usually low in total solids.

§ 41. The increase in total solids present in the ground water was not always accompanied by an increase in its height. Our observations on the relation of these—increase in height of ground water and total solids contained—are not quite consonant with one another, but they agree that the effect of the addition of considerable quantities of water applied to the surface is to increase the amount of salts in solution. Sometimes the increase in the amount of the salts in solution and that in the height of the water plane fell together, but at other times they did not.

§ 42. The influence of the changes in the water level, due to very light rains or other meteorological causes, was not marked enough to be noted without special study.

§ 43. The solids in the ground water during the season 1898, from May 24th till the end of October, were a little higher during the first two-thirds of the season, but lower during the last third, than in 1897; the water level was also very low, well D go-

ing dry about September 1, and B a month later, October 1. The differences in the individual wells were the same as in 1897, except in the extent of their variation.

§ 44. No attempt was made in 1899 to continue the study of the relation of the height of the water table to the amount of total solids contained in the water.

§ 45. The question whether the height of the water in the wells corresponded with the height of the water table in the soil was repeatedly suggested. Investigation showed that, for all of our purposes, it was safe to consider them the same.

§ 46. The matter was apparently different with the total solids present in the soil and well waters, especially in newly made holes in the soil, in which the solids were higher than in water from the near-by wells. This was not due to rain water falling directly into the wells, for they were covered to prevent this, nor to its running in from the surface, for the tiles which formed the lining of the wells projected above the surface sufficiently to escape this danger. The difference in the amount of salts present in the soil and well waters varied more than I expected them to. In one case, the water table being very high, within 18 inches of the surface, the difference in the amount of the total solids in the water taken from the soil and from the well, well A, was 2.6286 parts per thousand. In another portion of the plot where the water table was not so near to the surface, and where the soil was very different, the difference in the amounts of the total solids was only 0.4714 parts per thousand.

§ 47. It was unfortunately not feasible for us to determine whether the water drained into the wells from the surrounding soil, higher than the water plane, or not. If this took place at all it would seem that it did not drain from a very wide area, the radius of the soil affected must have been very small, or we would probably not have found so great a difference in the total solids present in the soil water and that of the wells. We made an attempt to determine the distance to which an under-drain would affect the height of the water table, and also to determine its influence upon the total solids present in the ground water at different distances from it; but as already stated, the experiment, owing to a variety of causes, was abandoned. The best data that I have bearing on this point was afforded by a well situated about two-thirds of the way from the east end of my plot to an under-drain east of and lower than the plot. The conditions here were in every respect better than in the plot under observation. They had probably not been so unfavorable to begin with, but assuming that they were the results of cultivation and drainage, the drain being about 70 feet from

this well, was to reduce the total solids to less than one-half the amount found in the easternmost well in my plot, 254 feet west of it. This difference held throughout the two years these wells were under observation. These data are not so good as would appear at first sight, for the plot had been under experimental cultivation for several years, five at least, and I have no means of judging to what extent, if any, the changes were due to the direct action of the drain upon this ground.

§ 48. If the water in the easternmost well was part of an eastward flow out of my plot, a large amount of the salts, 50 per cent., had been removed from solution in flowing from the eastern portion of my plot to the well, a distance of not more than 250 feet. The observations, however, upon the dissimilarity of the salt contents of the waters of the different wells justifies a serious doubt as to the existence of a flow through the soil, or if any, it is a slow one and is accompanied by an extremely slow translocation of the salts in the soil. It is certain that the soil has the power of retaining salts, but there are reasons for believing that there are marked differences in the soil in this respect, and if there were a flow, this property of the soil would tend to retard the translocation of the salts. Some facts supporting this view will be mentioned under the subject of drainage.

§ 49. There is another consideration which should be mentioned, the difference in the amount of salts in the water actually in contact with the soil and that in the wells may indicate that the true soil water coming into the wells from the sides may have received an admixture of water coming from below, and from which those salts most readily retained by the soil had been partially removed. If this were the case it would be strongly suggestive of a flow through the gravel, and as the well referred to entered the gravel, the water may have been a mixture of waters, some entering laterally from the soil and others rising vertically from the under-flowing waters. Such might be the case, even when the height of the water in the well and that in the soil outside of the well were the same, or so nearly so that refined means of measurement would have to be used to establish the difference.

§ 50. That the water flowing through the gravel, even if it were water percolating through the overlying soil, should differ in its content of salts from the water in the soil, is in keeping with the observed fact that the total solids present fell as the water table fell. The soil through which the water table fell not having reached its point of saturation for these salts, retained them until an equilibrium between those in solution and those present in the soil had been established.

§ 51. To what extent this well A and all the others were

affected by such mixing of waters has been a serious question throughout this work. The doubts entertained led me to have wells of different depths dug, and to endeavor to determine the extent to which samples of water obtained from slightly different depths taken from the same place and on the same date would differ. The results obtained prove beyond a doubt that the ordinary laws of solubility and diffusion are very radically modified and that the mixing of waters as suggested was improbable.

§ 52. I stated in Bulletin 46, page 5, that the water in the gravel stratum was different from the water in the soil proper. This appears, from the preceding statements, to be almost a matter of course; but there is a broader sense in which it might be the case, as I was at one time tempted to believe, *i. e.*, that the water in the gravel might be practically cut off from the water in the soil by the clayey stratum overlying the gravel, and that the water in the latter came from higher ground and constituted a sheet flowing eastward through it. The possibility that such might have been the case is evident, but I am satisfied that the clayey stratum did not suffice to separate the waters in the soil from that in the gravel, and I am doubtful whether the water from the higher land actually finds its way into the gravel as a distinct course for its flow. That it does not is indicated by our experience in June and July, 1899, when, because of an unusually large supply of water, the land to the west of us was excessively irrigated and the water table in our plot was raised to within eighteen inches of the surface. This water either flowed above the clayey stratum or rose through it.

§ 53. Transportation of the salts laterally through the soil did not, even in this case, seem to take place, for the individuality of the different wells was quite unaffected. Still the results of three seasons' cultivation, irrigation included, shows the removal of large quantities of soluble salts, if the amount of these held in solution by the soil waters be a reliable index. Taking the total solids in the waters of the different wells, ten days after irrigation, August 20, 1897, and August 31, 1899, we have wells A, B, C, and D showing the following total solids respectively in 1897: 30.8571, 35.2857, 3.3429 and 2.6429 parts per thousand; in 1899, 1.7857, 2.7286, 2.8857 and 3.4000 parts per thousand. In the case of Well D, in 1899, we have an increase, but after making allowance for all minor variations and a marked capriciousness in the amount of salts dissolved, there is still evidence of the removal of large amounts of the soluble salts from the soil.

§ 54. The crops, as shown in Bulletins 46 and 58, did not remove these salts, and if they did not remain more generally distributed through the mass of the soil, whereby they would be rendered more difficultly soluble in water, they must have been

removed by drainage even though we were unable to detect the flow.

CHLORIN IN THE GROUND WATER.

§ 55. The amount of chlorin in the ground water was not at any time extremely high. The maximum for 1897 was 0.2400 parts per thousand, unless we include one abnormal result obtained immediately after irrigating the plot, in which case we have 0.3429 parts per thousand; this result stands alone for 1897. The same well, however, in 1898 showed two such variations reaching 0.3143 parts per thousand after an irrigation, and 0.5286 parts on May 16th. The month had been wetter than usual, 2.9 inches of rain having fallen up to this date. With these exceptions this well was not so high in chlorin as two of the other three.

§ 56. The ratio of the chlorin to the total solids in the water ranged from 1:18 to 1:25 for well A from May, 1897, till May 1, 1898; for well B it ranged from 1:15 to 1:19; for well C from 1:18 to 1:22; and for well D from 1:16 to 1:22. In other words the salt, NaCl, found in the water did not, at any time during the year, amount to quite 1-9 of the total matter held in solution by the water and fell as low, in round numbers, as 1-16 of the total solids. In 1898 the ratio of the chlorin to the total solids for the respective wells varied as follows: for A, from 1:13 to 1:21; for B, from 1:14 to 1:16; for C, from 1:11 to 1:27; and for D, from 1:18 to 1:33. The largest amount of salt, NaCl, present equalled 1-7 and the smallest 1-20, or from 14.3 per cent. down to 5.0 per cent. of the total solids present. The latter part of the season of 1898 was quite dry and the water table fell so that some of the wells went dry. The total solids fell with the water table and so did the chlorin, but not proportionately with the total solids; the latter fell from 4.1857 parts per thousand on May 23 to 2.3429 parts on November 7, and the former fell from 0.32400 parts to 0.11071 parts per thousand in the same time. The total solids fell by a little less than one-half their quantity, while the chlorin fell by two-thirds of the amount present when the water table was high, May 23.

§ 57. The chlorin in the water was no indication of the amount of total solids present except within the very wide limits given above, which were different for each individual well; furthermore its quantity varied with the falling of the water table differently from that of the total solids, and increased in a most irregular manner when it rose, especially when the rising of the water table was due to irrigation or to heavy rainfalls. Experiments made by filtering salt solutions through sandstones have shown that they have a considerable power to retain it. Something similar prob-

ably takes place in this case, but the conditions of equilibrium between the salt solution and the soil are changed, perhaps are constantly changing, and the soil retains more of the sodic chlorid as the water table falls, or gives it up as it rises, sometimes in a most irregular fashion. Evaporation from the surface and capillarity undoubtedly influence these changes continuously. This view seems so fully conformable to what we know concerning the deportment of mixed salt solutions when in contact with soil that one is tempted to assert it as a demonstrated fact.

§ 58. Two experiments were made in the hope of gaining definite data relating to it. An excavation was made and a sample taken as soon as the water table was entered, a second sample was taken one foot below this, the water from the first foot being cut off as completely as possible so that the second sample represented water from the soil one foot below the water table; a third sample was taken at a depth of an additional foot with the same precautions. The respective samples showed the presence of 0.23286, 0.1771 and 0.1171 parts per thousand. Thirteen days later we repeated this experiment, choosing another portion of the plot for our observations. The sample of water taken at the surface of the water table contained 0.2129 parts, and the second one, taken a foot below the surface, showed the presence of 0.1457 parts per thousand. Two other samples were taken at greater depths, but the inflow of water was so great that the results were not so reliable. They showed, however, essentially the same as the second sample.

§ 59. The ratios of the chlorin to the total solids in the two experiments are not concordant and permit no inference whatever to be drawn from them. These facts establish what I have elsewhere stated, that the order of solubility of the different salts and the laws of diffusion are greatly modified by the properties of the soil particles and the relative masses of the soil water and the soil.

§ 60. The effect of irrigation, particularly when sufficient to raise the height of the water table, was to increase the absolute quantity of chlorin in the water, but not proportionately with the other salts. There were differences in the wells in this respect. The ratio of the chlorin to the total solids in well D before irrigation was 1:34, and after irrigation 1:64; in wells A and B the changes were in the same direction, but much less; in the case of well C the change in the ratio, though small, was in the opposite direction. The local conditions, including variations in the soil, seem to influence the amounts of the salts taken into solution and especially the relative quantities of the same. The soil in the vicinity of well C contained, according to analysis, more than twice as much chlorin

as the soils in the vicinity of the other wells. The water soluble in this soil was less than in that about well A, but greater than in that about wells B and D for both the first and second two inches. The percentages of chlorin in the water soluble portions of the soils are not very different, but it is not probable that the salts present in the soils are the same. The whole of the chlorin may be present in the form of ordinary salt in one case and in the form of magnesic or some other chlorid in the other; this seems to be the actual case for we were unable to combine the results of the analyses of these different water soluble portions in the same manner.

§ 61. It was hoped that the amount of the chlorin in the water and its variation from time to time might throw some light upon the movement of the alkali salts in the soil; but these seem so dependent upon local conditions and the character of the soil that no general deductions are justified.

TOTAL SOLIDS.

§ 62. The term total solids is here equivalent to alkali salts in solution in the ground water, and these are not the same as those which form the alkali incrustations, nor are they equal to the water soluble portion of the soil. These are three different mixtures of salts.

§ 63. It has been given as the result of three seasons' observation on this plot that the amount of the total solids varied in different portions, as shown by the fact that the wells differed from one another in this respect, and that there was no relation in the rate or extent of their variations. This is not the case with the composition of the solids held in solution, as shown by more than one hundred complete analyses of the waters of the different wells.

§ 64. I wish to emphasize the statement that the well waters represent the composition of all the water flowing into the well, between the surface of the water table and the bottom of the well, also possibly of water coming from the gravel below the well, for it is certain that however abnormally the salts may diffuse through the solution within the mass of the soil, they are entirely relieved from the influence of the soil particles in the free water accumulating in the wells. These well waters probably represent the average free solution in the soil for a depth represented by the height of the water plane above the bottom of the well, especially if there is no hydrostatic pressure forcing water upward out of a more porous stratum, as might have been the case in some of my wells where they entered the gravel.

§ 65. I have two analyses which, taken with the conditions under which the samples were collected, will fully present this

view. They are of water from wells designated as B and G respectively. Well B was put down in May, 1897, and had been open for a year at the time the sample in question was taken; well G was put down the day the sample was taken. Well B reached the gravel at a depth of 6 feet, while well G was but 4 feet deep, leaving about 2 feet of a difficultly pervious soil between the bottom of the well and the gravel. The analyses of the two samples follow:

TABLE I.—ANALYSIS OF WATER FROM WELL B, MAY 30, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.541	1.176	Calcic Sulfate	39.704	86.317
Sulfuric Acid	45.871	99.724	Magnesic Sulfate	24.934	54.207
Carbonic Acid	3.318	7.214	Potassic Sulfate	0.370	0.795
Chlorin	6.239	13.563	Sodic Sulfate	10.173	22.166
Sodic Oxid	15.165	32.969	Sodic Clorid	10.292	22.376
Potassic Oxid	0.200	0.435	Sodic Carbonate	7.994	17.378
Calcic Oxid	16.361	35.568	Sodic Silicate	1.099	2.389
Magnesic Oxid	8.304	18.054	Ferric and Alu. Oxids	0.031	0.067
Ferric and Alu. Oxids	0.031	0.067	Manganic Oxid	0.021	0.045
Manganic Oxid	0.021	0.045	Ignition	5.235	11.381
Ignition	5.235	11.381			
			Sum	99.853	217.073
Sum	101.286	220.196	Excess Sodic Oxid	0.223	0.050
Oxygen Eq. to Chlorin	1.406	3.057			
			Total	99.876	217.123
Total	99.880	217.139			

Total solids 3.1057 parts per thousand, or 217.4 grains per imperial gallon.

TABLE II.—ANALYSIS OF WATER FROM WELL G, MAY 30, 1898.

Analytical Results.	*Per Cent.*	*Grs Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.665	1.350	Calcic Sulfate	38.430	78.013
Sulfuric Acid	46.504	93.997	Magnesic Sulfate	24.897	50.541
Carbonic Acid	3.580	7.267	Potassic Sulfate	0.212	0.430
Chlorin	6.226	12.639	Sodic Sulfate	12.444	25.261
Sodic Oxid	16.450	33.394	Sodic Chlorid	10.247	20.855
Potassic Oxid	0.115	0.233	Sodic Carbonate	8.632	17.523
Calcic Oxid	15.831	32.137	Sodic Silicate	0.997	2.024
Magnesic Oxid	8.297	16.843	Ferric and Alu. Oxids	0.041	0.083
Ferric and Alu. Oxids	0.041	0.083	Manganic Oxid	0.041	0.083
Manganic Oxid	0.041	0.083	Ignition	4.102	8.327
Ignition	4.102	8.327			
			Sum	100.073	203.140
Sum	101.652	206.353	Excess Silicic Acid	0.174	0.353
Oxygen Eq. to Chlorin	1.403	2.848			
			Total	100.244	203.493
Total	100.249	203.505			

Total solids 6.7285 parts per thousand, or 203 grains per imperial gallon.

§ 66. These two analyses differ slightly in the ratics of the respective salts to the total solids, but serve to justify the statement made above that the well waters may be assumed to faithfully represent the composition of the freely circulating waters within the soil to the depth of the well. This is still the case when the water

level changes. The samples, of which analyses have just been given, were taken when the water plane was relatively high and the ground water contained rather more than 28.5714 parts per thousand. The following sample was taken when the water plane had been raised by irrigating the plot, and the total solids present in the water were almost 70 per cent. higher than on May 30th, when the preceding samples were taken. While there are some differences, they are comparatively small, which fact appears most clearly from the percentage composition of the total solids as given by the direct results of the analysis which follows:

TABLE III.—ANALYSIS OF WATER FROM WELL G, JULY 11, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.337	1.149	Calcic Sulfate	32.866	112.073
Sulfuric Acid.........	46.106	157.221	Magnesic Sulfate.....	27.162	92.622
Carbonic Acid........	3.456	11.785	Potassic Sulfate......	1.845	6.283
Chlorin............	6.317	21.541	Sodic Sulfate.........	13.897	47.389
Sodic Oxid...........	17.165	58.533	Sodic Chlorid........	10.424	35.546
Potassic Oxid........	1.002	3.417	Sodic Carbonate......	8.333	28.416
Calcic Oxid	13.539	46.168	Sodic Silicate........	0.684	2.332
Magnesic Oxid.......	9.052	30.867	Ferric and Alu. Oxids	0.070	0.239
Ferric and Alu. Oxids	0.070	0.239	Manganic Oxid.......	0.060	0.205
Manganic Oxid.......	0.060	0.205	Ignition..............	4.352	14.840
Ignition..............	4.352	14.840			
Sum............	101.456	345.965	Sum	99.693	339.945
Oxygen Eq. to Chlorin	1.423	4.852	Excess Sodic Oxid....	0.337	1.149
Total..........	100.033	341.113	Total..........	100.030	341.094

Total solids 4.7714 parts per thousand, or 341.0 grains per imperial gallon.

§ 67. What has just been said is true of the water of all of the wells throughout the three seasons during which we had them under observation.

§ 68. The salts present, that is constituting the total solids, in the waters are calcic, magnesic, and sodic sulfates with sodic carbonate and chlorid.

§ 69. In the analyses already given, and in those to follow, I have combined the acids and basis in the order adopted in Bulletin 65, believing that this order represents as nearly as any other which might have been adopted, the salts which actually exist in the solution. It is certainly not always correct, but it gives us an easy and uniform method of statement. That it is not correct in every case is clear, for the sodic carbonate appears in the analysis as the normal salt, which when present in the quantities shown by the analyses, ought to react with phenolphthalein, but it does not, and is probably present wholly as the acid carbonate or bicarbonate. The total carbonic acid in the waters as they were taken from the wells was not determined, still there is no doubt but that

the sodic carbonate existed essentially if not wholly as a bicarbonate. Again the calcic sulphate appears in the analysis without any water of crystallization, but it is in no way intended to state that calcic sulphate was actually present as anhydrite. I do not think it possible to tell just how these groups were arranged in the solution, how many of them were free and how many of them combined, but I simply present the probable combinations as an easy and convenient way of expressing our results. The statement of the analysis is so full that further explanation is unnecessary.

§ 70. I find it a common thing, almost a rule, that the analyses show a slight excess of sodic oxid, sometimes, however, the excess is silicic acid. I have also found this to be a common result in the analysis of alkali incrustations. I attributed this excess to the probable presence of organic acids. Examinations for volatile organic acids did not justify the assumption of the excess being due to their presence, for I found them present in very minute quantities. The excess of sodic oxid is usually higher when the loss on ignition is high, than it is when this loss is low. The excess is often very insignificant and within the limits of analytical errors.

§ 71. For the purpose of presenting the general composition of the well waters I will give analyses of samples taken in the month of July, 1897 and 1898, because I think that the samples of this month show less uniformity than those of any other in which regular samples were taken. The following are all of the samples taken from these wells during this month, except some taken immediately after irrigation.

TABLE IV.—ANALYSIS OF WATER FROM WELL A, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.474	1.223	Calcic Sulfate	36.500	94.207
Sulfuric Acid	48.853	126.090	Magnesic Sulfate	28.795	74.320
Carbonic Acid	1.997	5.154	Potassic Sulfate	0.594	1.533
Chlorin	5.598	14.448	Sodic Sulfate	13.995	36.121
Sodic Oxid	14.373	37.097	Sodic Chlorid	9.233	23.830
Potassic Oxid	0.321	0.829	Sodic Carbonate	4.815	12.428
Calcic Oxid	14.999	38.712	Sodic Silicate	0.963	2.486
Magnesic Oxid	9.596	24.767	Ferric and Alu. Oxids	0.177	0.457
Ferric and Alu. Oxids	0.177	0.457	Manganic Oxid	0.143	0.369
Manganic Oxid	0.143	0.369	Ignition	4.410	11.382
Ignition	4.410	11.382	Sum	99.625	257.133
Sum	100.941	260.528	Excess Sodic Oxid	0.054	0.139
Oxygen Eq. to Chlorin	1.261	3.255	Total	99.679	257.272
Total	99.680	257.273			

Total solids 3.6871 parts per thousand, or 258.1 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE V.—ANALYSIS OF WATER FROM WELL A, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.547	1.456	Calcic Sulfate	37.366	99.468
Sulfuric Acid	45.209	120.346	Magnesic Sulfate	25.568	68.061
Carbonic Acid	2.140	5.696	Potassic Sulfate	0.106	0.281
Chlorin	6.475	17.235	Sodic Sulfate	10.903	29.025
Sodic Oxid	14.114	37.572	Sodic Chlorid	10.681	28.433
Potassic Oxid	0.057	0.152	Sodic Carbonate	5.155	13.721
Calcic Oxid	15.397	40.988	Sodic Silicate	1.111	2.958
Magnesic Oxid	8.515	22.668	Ferric and Alu. Oxids	0.091	0.243
Ferric and Alu. Oxids	0.091	0.243	Manganic Oxid	0.037	0.099
Manganic Oxid	0.037	0.099	Ignition	8.621	22.948
Ignition	8.621	22.948	Sum	99 639	265.237
Sum	101.203	269.403	Excess Sodic Oxid	0.101	0.268
Oxygen Eq. to Chlorin	1.459	3.884	Total	99.740	265.505
Total	99.744	265.519			

Total solids 3.8028 parts per thousand, or 266.2 grains per imperial gallon.

TABLE VI.—ANALYSIS OF WATER FROM WELL B, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.646	1.406	Calcic Sulfate	34 359	74.765
Sulfuric Acid	46.912	102.081	Magnesic Sulfate	24.903	54.189
Carbonic Acid	2 166	4.713	Potassic Sulfate	0.982	2.137
Chlorin	5.795	12.610	Sodic Sulfate	17.149	37.316
Sodic Oxid	16.679	36 294	Sodic Chlorid	9.558	20.798
Potassic Oxid	0.531	1.155	Sodic Carbonate	5.223	11.365
Calcic Oxid	14.158	30.808	Sodic Silicate	1.312	2.855
Magnesic Oxid	8.299	18.059	Ferric and Alu. Oxids	0.141	0.307
Ferric and Alu. Oxids	0.141	0.307	Manganic Oxid	0.070	0.152
Manganic Oxid	0.070	0.152	Ignition	5.909	12.858
Ignition	5.909	12 858	Sum	99.606	216.742
Sum	101.306	220.443	Excess Sodic Oxid	0.394	0.856
Oxygen Eq. to Chlorin	1.306	2.842	Total	100.000	217.598
Total	100.000	217.601			

Total solids 3.1085 parts per thousand, or 217.6 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE VII.—ANALYSIS OF WATER FROM WELL B, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.619	1.750	Calcic Sulfate	34.339	97.076
Sulfuric Acid	45 837	129.581	Magnesic Sulfate	23 141	65.420
Carbonic Acid	2 561	7.240	Potassic Sulfate	0.186	0.526
Chlorin	6 413	18.129	Sodic Sulfate	17.988	50.852
Sodic Oxid	17.849	50.459	Sodic Chlorid	10.583	29.918
Potassic Oxid	0.101	0.286	Sodic Carbonate	6.175	17.457
Calcic Oxid	14.146	39.981	Sodic Silicate	1.258	3.556
Magnesic Oxid	7.712	21.802	Ferric and Alu. Oxids	0.030	0.085
Ferric and Alu. Oxids	0.030	0.085	Manganic Oxid	0.030	0.085
Manganic Oxid	0.030	0.085	Ignition	6.117	17.293
Ignition	6.117	17.293	Sum	99.847	282.268
Sum	101.415	286.691	Excess Sodic Oxid	0.121	0.342
Oxygen Eq. to Chlorin	1.445	4.085	Total	99.968	282.610
Total	99 970	282.606			

Total solids 4.0385 parts per thousand, or 282.7 grains per imperial gallon.

TABLE VIII.—ANALYSIS OF WATER FROM WELL C, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid..........	0.408	0.816
Sulfuric Acid........	50.288	100.576
Carbonic Acid........	2.550	5.100
Chlorin...............	3.294	6.588
Sodic Oxid..........	15.651	31.302
Potassic Oxid........	0.341	0.682
Calcic Oxid..........	16.854	33.708
Magnesic Oxid.......	7.623	15 246
Ferric and Alu. Oxids	0.260	0 520
Manganic Oxid.......	0.137	0.274
Ignition..............	3.661	7.322
Sum...........	101.067	202.134
Oxygen Eq. to Chlorin	0.741	1.482
Total..........	100.326	200.652

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate........	40.901	81.802
Magnesic Sulfate.....	22.874	45.748
Potassic Sulfate......	0.631	1.262
Sodic Sulfate.........	19.003	38.006
Sodic Chlorid........	5.433	10.866
Sodic Carbonate......	6.149	12.298
Sodic Silicate........	0.829	1.658
Ferric and Alu. Oxids	0.260	0.520
Manganic Oxid.......	0.137	0.274
Ignition..............	3.661	7.322
Sum...... ...	99 878	199.756
Excess Sodic Oxid....	0.447	0.894
Total..........	100.325	200.650

Total solids 2.5714 parts per thousand, or 200.0 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE IX.—ANALYSIS OF WATER FROM WELL C, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid..........	0.609	1.121
Sulfuric Acid..........	46.151	84.965
Carbonic Acid........	3.911	7 201
Chlorin...............	4.770	8.781
Sodic Oxid...........	19.651	36.177
Potassic Oxid........	0.015	0.028
Calcic Oxid..........	12.672	23.329
Magnesic Oxid..	8.200	15.097
Ferric and Alu. Oxids	0.045	0.082
Manganic Oxid.......	0.040	0.073
Ignition...............	4.938	9.090
Sum...........	101 002	185.944
Oxygen Eq. to Chlorin	1.075	1.979
Total..........	99.927	183.965

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate........	30.752	56.615
Magnesic Sulfate.....	24.622	45.329
Potassic Sulfate......	0.029	0.053
Sodic Sulfate........	20.666	38.047
Sodic Chlorid........	7.869	14.486
Sodic Carbonate.....	9.423	17.348
Sodic Silicate........	1.237	2.278
Ferric and Alu. Oxids	0.045	0.082
Manganic Oxid.......	0.040	0.073
Ignition..............	4.938	9.090
Sum...........	99.621	183.401
Excess Sodic Oxid....	0.304	0.560
Total..........	99.925	183.961

Total solids 2.6300 parts per thousand, or 184.1 grains per imperial gallon.

TABLE X.—ANALYSIS OF WATER FROM WELL D, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicate Acid.........	0.639	1.040
Sulfuric Acid........	45 490	74 012
Carbonic Acid........	2.351	3.825
Chlorin.....	5.765	9.380
Sodic Oxid...........	18.578	30.226
Potassic Oxid.........	0.191	0.311
Calcic Oxid..........	14.619	23.785
Magnesic Oxid........	6.351	10.333
Ferric and Alu. Oxids	0.639	1.040
Manganic Oxid.......	0.067	0.109
Ignition..............	6.579	10.704
Sum...........	101.269	164 765
Oxygen Eq. to Chlorin	1.299	2.113
Total..........	99.970	162.652

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate........	35.477	57.712
Magnesic Sulfate.....	19.057	31.006
Potassic Sulfate......	0.353	0.574
Sodic Sulfate.........	20.893	33.993
Sodic Chlorid	9.509	15.471
Sodic Carbonate......	5 669	9.223
Sodic Silicate.........	1.298	2.112
Ferric and Alu. Oxids	0.639	1.040
Manganic Oxid.......	0.067	0.109
Ignition..............	6 579	10.704
Sum...........	99.541	161.953
Excess Sodic Oxid....	0.429	0 698
Total..........	99.970	162.651

Totol solids 2.3242 parts per thousand, or 162.7 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE XI.—ANALYSIS OF WATER FROM WELL D, JULY 19, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.539	1.103	Calcic Sulfate	36.851	75.435
Sulfuric Acid	45.095	92.309	Magnesic Sulfate	20.789	42.555
Carbonic Acid	2.695	5.517	Potassic Sulfate	0.638	1.306
Chlorin	6.271	12.837	Sodic Sulfate	16.472	33.718
Sodic Oxid	17.089	34.981	Sodic Chlorid	10.343	21.172
Potassic Oxid	0.345	0.706	Sodic Carbonate	6.498	13.301
Calcic Oxid	15.185	31.084	Sodic Silicate	1.095	2.241
Magnesic Oxid	6.928	14.182	Ferric and Alu. Oxids	0.207	0.424
Ferric and Alu. Oxids	0.207	0.424	Manganic Oxid	0.061	0.125
Manganic Oxid	0.061	0.125	Ignition	6.490	13.285
Ignition	6.490	13.285	Sum	99.444	203.562
Sum	100.995	206.553	Excess Sodic Oxid	0.047	0.096
Oxygen Eq. to Chlorin	1.413	2.892	Total	99.491	203.658
Total	99.492	203.661			

Total solids 2.9242 parts per thousand, or 204.7 grains per imperial gallon.

TABLE XII.—ANALYSIS OF WATER FROM WELL D, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.520	1.203	Calcic Sulfate	35.466	82.033
Sulfuric Acid	46.633	107.862	Magnesic Sulfate	23.883	55.241
Carbonic Acid	3.217	7.441	Potassic Sulfate	0.178	0.412
Chlorin	3.067	7.094	Sodic Sulfate	17.353	40.137
Sodic Oxid	15.448	35.731	Sodic Chlorid	5.059	11.701
Potassic Oxid	0.096	0.222	Sodic Carbonate	7.757	17.942
Calcic Oxid	14.610	33.793	Sodic Silicate	1.056	2.443
Magnesic Oxid	7.959	18.409	Ferric and Alu. Oxids	0.087	0.201
Ferric and Alu. Oxids	0.087	0.201	Manganic Oxid	0.087	0.201
Manganic Oxid	0.087	0.201	Ignition	8.821	20.404
Ignition	8.821	20.404	Sum	99.747	230.715
Sum	100.545	232.561	Excess Sodic Oxid	0.107	0.248
Oxygen Eq. to Chlorin	0.691	1.598	Total	99.854	230.963
Total	99.854	230.963			

Total solids 3.30429 parts per thousand, or 231.3 grains per imperial gallon.

§ 72. These analyses present the highest limit of the sulfates not only for this month but for the whole time that the plot was under observation. The sample from well C, taken July 5, 1897, six days after irrigation, shows the presence of 50.29 per cent. sulfuric acid, SO_3, which is nearly 1.5 per cent. higher than the next highest one given and is the highest, with one exception, in the whole series representing the three seasons' work. That the average percentage of sulfuric acid for all of the analyses made of these well waters is lower than that shown by these for the month of July may be inferred from the fact that there are only 8 in the 105 analyses made showing 48 per cent. or more of this constituent.

§ 73. The analyses given show almost as great a range in the quantity of chlorids present as the whole number of samples taken. There are only a few exceptional samples which show either higher or lower figures for the chlorids than those given.

§ 74. These samples also serve to represent the general composition of the total solids present in this class of ground waters. As a matter of course it is not intended that one shall infer from this statement that the alkaline ground waters occurring in different parts of the state are so rich in total solids or that the different salts are present in the same proportions, but that the ground waters in alkalied sections are of this general type. I have not yet found any ground water materially richer in sodic chloride (common salt) or sodic carbonate. It is true that some surface well waters that have come to hand for analysis, have shown relatively much larger amounts of carbonates, while the total solids were materially less in quantity. These waters were from wells sunk for the purpose of obtaining potable water, or water for use in boilers, and I assume that the samples represented the best procurable quality of such waters.

§ 75. The following analysis of a water struck at a depth of 28 feet and occurring in a two-foot stratum of sand, will serve for comparison with the analyses of ground waters already given. This sample of water was sent to us from Rockyford, in the Arkansas Valley:

TABLE XIII.—ANALYSIS OF WATER FROM ROCKYFORD, JULY 26, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.141	0.880	Calcic Sulfate	15.206	94.870
Sulfuric Acid	45.136	281.603	Magnesic Sulfate	29.059	181.299
Carbonic Acid	3.989	24.887	Potassic Sulfate	Trace	Trace
Chlorin	3.772	23.533	Sodic Sulfate	29.865	186.328
Sodic Oxid	22.277	138.986	Sodic Chlorid	6.224	38.832
Potassic Oxid	Trace	Trace	Sodic Carbonate	9.619	60.013
Calcic Oxid	6.264	39.081	Sodic Silicate	0.286	1.784
Magnesic Oxid	9.684	60.418	Ferric and Alu. Oxids	0.010	0.062
Ferric and Alu. Oxids	0.010	0.062	Manganic Oxid	0.040	0.250
Manganic Oxid	0.040	0.250	Ignition	9.233	57.605
Ignition	9.233	57.605	Sum	99.542	621.043
Sum	100.546	627.307	Excess Sodic Oxid	0.152	0.948
Oxygen Eq. to Chlorin	0.850	5.303	Total	99.694	621.991
Total	99.696	622.004			

Total solids 8.9129 parts per thousand, or 623.9 grains per imperial gallon.

§ 76. A sample of ground water from this locality, Rockyford, taken under my own directions, but at a depth of 12 feet, differed from the above in the relative amounts of calcic and magnesic sulfates, but the quantities of sodic sulfate and chlorid were nearly the same.

§ 77. There is, as I have previously intimated, probably a difference between samples taken as soon as the water plane has been entered and after the well has been emptied several times by continued pumping or bailing; there is, besides, in shallow wells

at least, a difference due to the conditions which prevailed immediately prior to the time of taking the sample.

§ 78. Outside of these general features but little is shown by the composition of the ground waters as collected in the wells. The changes observed are not so great as were looked for, and when the variations due to changes in conditions immediately before the taking of the samples have been allowed for, the uniformity throughout the period of observation, a period of nearly three years, leaves but little doubt of the correctness of the conclusion that, while the total solids may vary in their quantity and in composition, too, within narrow limits, they remain in all essential respects the same.

THE GROUND WATERS DIFFERENT FROM ALKALIES—ALSO FROM THE DRAIN WATERS.

§ 79. The total solids, obtained by evaporating the ground waters, represent a different mixture of salts than that which is obtained by continued treatment of the soil with frequently renewed portions of distilled water, until it is so thoroughly exhausted that no sulfuric acid can be found in the solution after standing in contact with the soil for not less than 12 hours. Attention was called to this fact in Bulletin 65, where some analyses of the water-soluble portions of this soil are given, together with their most characteristic features.

§ 80. In the following comparison we shall not make any attempt to assign causes for the differences which are undoubtedly to be found in the complex reactions taking place between the different salts or their ions within the mass of the soil, and also to the formation of salts de novo, due to the action of water as such, and of solutions upon the rock particles in the soil. In Bulletin 65 the suggested explanation was confined almost wholly to the latter phase of the question because it is the simplest feature of it and conveys a sufficiently extensive view of the subject without introducing any of the more difficult questions involved in the theory of solutions. For a fuller and sufficient explanation of the facts recourse must be had to this branch of the subject, but I shall content myself with as clear a statement of the facts as I may be able to make.

§ 81. The samples which I have chosen are a sample of water from well C, the water soluble portions from two samples of soil C and a representative alkali incrustation. The designation well C and soil C is equivalent to stating that the sample of soil was taken as near to well C as we deemed advisable, which in this case was within 11 feet.

§ 82. It is difficult to present this subject without reproducing all of the analyses representing the different sections of the plot, for they differ so much in character that one is not really representative of the plot. The suggested difficulties are still greater than the simple lack of representativeness, for it suggests that the chemical reactions taking place within very limited areas of soil may be but partially or not at all comparable. This difference is made strikingly evident by the difference in the salts present in the water-soluble portions of the first and second two inches of these soils. Whether I have adopted the proper order of combination or not does not matter. I have adopted the same method of interpretation in all cases, which in itself may be an error, still it brings out several important and scarcely questionable differences.

§ 83. I shall select section C for my present purpose, because it is less favorable to my presentation of this subject than B or D, and rather more favorable than section A. The reader who wishes to compare the results obtained for the other sections can find the analyses of the water-soluble portions of the soil in Bulletin 65, pages 36, 37 and 38.

§ 84. The samples of soil were taken, one in May and the other in June. The sample of water was taken in June. It would have been better for the present purpose had they been taken at the same time as well as from the same place, but I have chosen these from the samples taken, as being the nearest together in the point of time of collecting.

§ 85. The alkali which I use in this case was also collected in June, but nearer to well A than to well C. This, however, does not detract from its value for the purpose of comparison, for other samples show that the differences in the alkali incrustations of this plot do not lie in the salts of which they are composed, but in their relative quantities. I have a sample taken nearer to well C, but it was taken in January during freezing weather, which, owing to the deportment of sodic sulfate at low temperatures, might make it less comparable than the one chosen.

The arrangement of the analyses is evident.

TABLE XIV.—ANALYSIS OF ALKALI, INCRUSTATION.

Analytical Results.	*Per Cent.*	*Combined.*	*Per Cent.*
Silicic Acid	0.491	Calcic Sulfate	7.404
Sulfuric Acid	52.403	Magnesic Sulfate	26.859
Carbonic Acid	0.730	Potassic Sulfate	0.088
Chlorin	2.004	Sodic Sulfate	53.450
Sodic Oxid	26.797	Sodic Chlorid	3.307
Potassic Oxid	0.048	Sodic Carbonate	1,760
Calcic Oxid	3.050	Sodic Silicate	0.997
Magnesic Oxid	8.951	Ferric and Alu. Oxids	0.030
Ferric and Alu. Oxids	0.030	Manganic Oxid	0.129
Manganic Oxid	0.129	Ignition	5.384
Ignition	5 384		
Sum	100.017	Sum	99 408
Oxygen Eq. to Chlorin	0.451	Excess Sodic Oxid	0.157
Total	99.566	Total	99.565

TABLE XV.—ANALYSIS WATER-SOLUBLE, SOIL C, FIRST TWO INCHES.

Analytical Results.	*Per Cent.*	*Combined.*	*Per Cent.*
Silicic Acid	1.084	Calcic Sulfate	43.260
Sulfuric Acid	48.826	Magnesic Sulfate	24 260
Phosphoric Acid	None	Potassic Sulfate	2.475
Carbonic Acid	0 385	Sodic Sulfate	10.789
Chlorin	4.321	Sodic Chlorid	7.128
Potassic Oxid	1 338	Sodic Carbonate	0 928
Sodic Oxid	10.190	Sodic Silicate	2 202
Calcic Oxid	17.826	Ferric and Alu. Oxids	———
Magnesic Oxid	8.080	Manganic Oxid	0.342
Ferric and Alu. Oxids	———	Ignition	8.281
Manganic Oxid	0 342	Sum	99.665
Ignition	8.281	Excess Sodic Oxid	0.031
Sum	100.673	Total	99.696
Oxygen Equivalent to Chlorin	0 973		
Total	99.700		

The percentage of water-soluble equalled 2.0544.

TABLE XVI.—ANALYSIS WATER-SOL., SOIL C, SECOND TWO INCHES.

Analytical Results.	*Per Cent.*	*Combined*	*Per Cent.*
Silicic Acid	9.095	Calcic Sulfate	50.917
Sulfuric Acid	34.832	Magnesic Sulfate	3.197
Phosphoric Acid	0.522	Potassic Sulfate	6.016
Carbonic Acid	5.558	Magnesic Phosphate	0.963
Chlorin	2.663	Magnesic Chlorid	3.565
Potassic Oxid	3.252	Magnesic Carbonate	8.646
Sodic Oxid	8.778	Sodic Carbonate	2.490
Calcic Oxid	20.981	Sodic Silicate	14.418
Magnesic Oxid	7.131	Ferric and Alu. Oxids	0.898
Ferric and Alu. Oxids	0.878	Manganic Oxid	0.245
Manganic Oxid	0.245	Ignition	6.996
Ignition	6.996	Sum	98.351
Sum	100.951	Excess of Silicic Acid	1.998
Oxygen Equivalent to Chlorin	0.600	Total	100.349
Total	100.351		

The percentage of water-soluble equalled 0.813.

TABLE XVII.—ANALYSIS OF WATER FROM WELL C, JUNE 13, 1898.

Analytical Results.	*Per Cent.*
Silicic Acid	0.656
Sulfuric Acid	44.875
Carbonic Acid	3.517
Chlorin	5.144
Sodic Oxid	18.108
Potassic Oxid	0.058
Calcic Oxid	14.445
Magnesic Oxid	7.167
Ferric and Alu. Oxids	0.026
Manganic Oxid	0.041
Ignition	6.911
Sum	100.948
Oxygen Equivalent to Chlorin	1.159
Total	99.789

Combined.	*Per Cent.*
Calcic Sulfate	35.054
Magnesic Sulfate	21.520
Potassic Sulfate	0.107
Sodic Sulfate	17.517
Sodic Chlorid	8.487
Sodic Carbonate	8.474
Sodic Silicate	1.333
Ferric and Alu. Oxids	0.026
Manganic Oxid	0.041
Ignition	6.911
Sum	99.470
Excess Sodic Oxid	0.316
Total	99.786

§ 86. The alkali or incrustation which collected on the surface of the soil is essentially a mixture of sodic and magnesic sulfates in the ratio of two to one. These two salts make up 80 per cent. of the whole mass. Calcic sulfate is subordinate in quantity, with sodic chlorid and carbonate still more so.

§ 87. In the first two inches of the soil we find that the soluble salts consist largely of calcic, magnesic and sodic sulfates, which together form 78.3 per cent. of them, with the calcic sulfate predominant. In the second two inches the calcic sulfate constitutes almost 51 per cent. of the water-soluble portion of the soil, with magnesic sulfate subordinate and sodic sulfate absent. On the other hand, sodic silicate, which is very subordinate in the alkali and ground water, is here next in quantity to the calcic sulfate, and the potassic sulfate, which is present in scarcely more than traces in the alkali given, makes about 1-16 of the water-soluble portion of the second two inches of the soil. The potassic salts in the alkali incrustations which I have examined and which were formed as efflorescences, are sometimes higher than in the one given, amounting in some cases to about 1 per cent. In an alkali from South Park, Colo., the potassic salts were a little over 8 per cent., but the conditions are wholly different from those prevailing in our plot.

§ 88. The variety of salts in the water-soluble portion of the soils seems to be greater and the relative quantities of the subordinate ones are much more nearly equal than in the alkali or the water. Reference to the analyses of the other water-soluble portions of the soils will show a tendency in this direction in the first two, but it is more marked in the second two inches of soil. In no case do we have an increase in the amount of the more soluble sodic and magnesic sulfates in the second two inches of soil, while that of the less soluble calcic sulfate is quite marked.

§ 89. The analyses of the waters from the wells agree with the one given in showing that the total solids in the ground water contain more calcic sulfate than the incrustations, but much less than the water-soluble portions of the soils, whether it is of the first or second two inches. The results of the analyses of other samples also agree relative to the magnesic sulfate, viz.: that there is almost as much in the water residues as there is in the incrustation or in the first two inches of the soil C, and more than in any of the other seven water-soluble portions examined.

§ 90. The most marked difference is shown in the case of the sodic sulfate, which makes up 53 per cent. of the alkali incrustation, 17 per cent. of the solids dissolved in the ground water, 10 per cent. of the water-soluble in the first two inches of the soil, and is absent in the second two inches. The analyses given above do not stand alone in indicating this difference, but many analyses, all that we have made of the ground waters and three other soil samples, indicate this to be a fact. Sodic sulfate is always a constituent of the total solids in the ground waters, varying in quantity from less than 5 per cent. to 23 per cent. I may state here, as an unlooked-for result, that this salt almost disappears from the drain water coming from this area.

§ 91. The appearance of these two salts, sodic and magnesic sulfates, in the incrustations, seems very reasonable if the suggestion made in Bulletin 65, that the incrustation is formed by an approximate separation of these efflorescent salts from the more permanent ones, especially calcic sulfate, at the contact of the water surface with the air, is correct. The suggestion of the formation of a double magnesic sodic sulfate lies near at hand in this case, but whatever the case may be, we are not justified by the ratio of the magnesic salt to the sodic salt in assuming its formation; besides there is no urgent need of it, as the deportment of these two sulfates toward the air surface is sufficiently different from that of calcic sulfate to permit of the separation as observed. The formation of these incrustations is very different from the simple evaporation of a solution of different salts to dryness, for these efflorescent salts are removed from the solution and its former status is changed.

§ 92. Why the sodic sulfate forms so small a percentage of the water-soluble portion of the soil is not easily explained. That it should sometimes be found in the upper portions of the soil in large quantities is to be expected, even if as a rule it were present in small quantities only or entirely absent, for the tendency is to a separation of it on the surface, whence it may be carried back into the soil by rain or abundant atmospheric moisture, being retained within the surface layers of the soil in which it may form a large percentage of the water-soluble portion. We have one instance in

which it forms 27 per cent. of it. But, remembering that this sulfate does not pass into the drain waters, while it usually exceeds 10 per cent., often rises above 17 and sometimes reaches 23 per cent. of the salts in the ground water, it seems strange that the water-soluble portion of the soil should so frequently give good reason for supposing it to be absent. I do not know any facts nor have I seen any statement of established or probable changes which will account for these facts as observed.

§ 93. The magnesic and sodic sulfates are both present in the ground water, or their ions are, and constitute the efflorescent salts passing out of solution at the surface of the soil, or where the surface of the solution comes in contact with the air. Evaporation is proceeding at this surface and the capillary movement of the ground water is rapid and free. for when the condition of the soil is such that we can sufficiently impede the capillary rise of the water, we prevent the formation of such incrustations. The result may be roughly presented as the movement of a free solution through the interstices of particles which are themselves not free to move, but capable of being modified in regard to their composition either by exchange or by attracting to themselves and retaining other salts. These processes may be subject to the greatest variety of modifications, so that they are not exclusive or constant, and seldom perfected, but vary from point to point within the soil.

§ 94. It has been accepted for a long time that soils as a rule have a high power of retaining potassic salts and but a very feeble one of retaining soda salts. If this were wholly correct, we should expect to find the drain waters from such areas as the one forming the subject of this study loaded with soda salts, at least to the same extent, if not to a much greater one, than the ground waters. But we do not find this to be the case, and the conditions are such that it is not probable that the difference is due to the dilution of the drain waters from this area by water from other sources.

§ 95. Under the subject of the total solids in the ground water, I stated the result of experiment to be an indication that they decreased with depth, that the first foot of water after entering the water plane was richer in total solids than the second, and so on. At first I did not believe this. An instance in point was well D, which on September 20th showed the presence of 3.4071 parts total solids per thousand. A temporary well opened on this date 40 feet south of well D, the surface contour and the character of the soil being the same but the sample of water being obtained at a greater depth, probably two feet deeper, showed only 2.18713 parts total solids per thousand. The residue from the water of well D showed the presence of 16.87 per cent. of sodic sulfate, while that from the newly opened one showed 14 per cent., a difference of

nearly 3 per cent. in this respect. In this case we almost certainly had an admixture of water from points above that at which we endeavored to collect the water, for with our appliances we could not prevent it. The drain waters, in which we have a better separation of the waters, show a still greater difference, both in the amount of the total solids and in the percentage of the sodic sulfate. We are justified in extending our statement that the ground water, in so far as it is a solution of salts, differs from the alkalis which effloresce, from the solution obtained by exhausting the soil with distilled water as previously described, and also from the drain water flowing from under the area.

LITHIA IN THE GROUND WATER.

§ 96. Reference has been made in a preceding bulletin to the failure of an attempt to determine the lateral movement of this salt through the soil, or the rate and direction of the flow of the ground water. The detection of lithia in the samples of water tested to ascertain with certainty that my experiment was actually a failure, led me to test a considerable number of samples of the ground water and also samples of drain water to ascertain whether its presence was accidental or whether its occurrence was general and constant. The result was that its presence was established qualitatively in every sample tested, and these represented samples taken during a period extending over more than two years. The quantity present was as a matter of course not large, but sufficient to be readily detected by the aid of the spectroscope, and in some of the samples sufficient for quantitative determination without great trouble. This element seems to be present in all of the water in this basin. Its presence was detected in the ash of beets grown upon this plot, and also in the ash of their leaves. This is peculiar for I have tested a number of ashes of alfalfa; some of it grown within this same swale and have never succeeded in detecting it.

NITRATES IN THE GROUND WATER.

§ 97. The results of the only determinations of the nitrates in the soil are given in Bulletin 65, page 45. The variation in the amount present in the different portions of the plot and also in the first and second two inches of soil is very considerable. The determinations are entirely conclusive that the conditions obtaining do not prevent the formation of nitric acid, and further, that its distribution in depth as well as from place to place throughout the plot is very uneven. The minimum quantity of nitric acid in a million parts of the air dried soil of the first two inches was 32 and the maximum 162; of the second two inches the minimum was a trace and the maximum was 9 parts. In A, the section of the plot where the conditions were most unfavorable to cultivation, there was 32

parts per million; in B, where the conditions of cultivation were good, but where we had trouble to obtain a good stand of plants and the ground water was generally the most heavily laden with total solids, the nitric acid was the highest, reaching 162 parts per million; in C, a section which is quite wet and yields incrustations, but in a less degree than A, the nitric acid falls to 55 parts per million, but it again rises to 86 parts per million in D, which section is in good condition and whose surface is always from 3.5 to 6 feet above the water table.

§ 98. We do not find nitric acid abundant in any portion of the plot in the second two inches, it being present in the sample from section A as a trace only, but it increases as the ground rises to the westward until it reaches a maximum of 9.3 parts per million in D.

§ 99. At the close of the season of 1897, 23 days before our crop was harvested, the ground water from the wells showed a range of total solids from 2561 to 3986 parts per million, while the nitric acid ranged from 4 to 7.8 parts. A sample of water taken from a newly made opening penetrating the gravel and quite near to the Town Ditch, an irrigating ditch, showed the presence of 2187 parts total solids and 11.34 parts of nitric acid per million. The water plane was low at the time these samples were taken.

§ 100. On the 16th of May, 1898, the level of the ground water was not especially high, but the total solids were exceptionally so, and the nitric acid in the waters of wells A and C was unprecedentedly high, 41 and 68 parts per million respectively, but this was not so in the case of wells B and D, which carried 5.0 and 2.7 parts respectively. From this date, May 16th, the nitric acid fell continuously till June 6th, when owing to a rainfall there was a change in the soil conditions, followed by an increase of nitric acid in wells A and D and by a decrease of it in wells B and C. From this time, June 6th, till July 14th, the water table gradually fell and so did the quantity of nitric acid present; the surface of the ground having become somewhat dry in the meantime. The plot received an irrigation on July 14th and the samples of water taken on the following day showed an increase in the amount of nitric acid present; but this increase was not uniform in the different wells. The water plane was raised according to the position of the wells, and the amount of water we were able to bring on the surrounding section, which varied, as we had only a scanty supply of water at our disposal. The effects of this irrigation upon the total solids held by the waters was as marked as any that I have had the opportunity of observing. Wells A, B and C rose from 28.0000, 29.2856 and 16.1429 parts per thousand on the 8th to 58.8571, 44.8571, and 58.1429 parts per thousand

on the 11th, while well D, probably due to accidental inflow of water from the surface, fell. The nitric acid rose in the meantime by 7 parts per million in A, 13 parts in B, 18 parts in C, and 1 part in D. The largest increase, however, was observed in a well sunk in an adjoining plot which had been manured and which chanced to receive an irrigation at this time. This well showed 3.59 parts of nitric acid per million on June 27th and 475.63 parts on July 9th. The water table was raised, in this case, almost to the surface.

§ 101. The duration of the effects of this irrigation upon the amount of nitric acid in the water was quite different in the different wells. The greatest increase in my plot was shown in the case of well C, which, throughout the season, proved to be the richest in nitric acid of any of the four wells here considered, and also of all the wells on my plot of ground. The water of this well carried on the 8th of July 2.69 parts nitric acid per million; this rose to 21.18 parts just after the irrigation and fell to 2.51 parts by August 1st. The nitric acid in well B did not increase to the same extent as in well C, but it fell a little more slowly, and on this date, August 1st, showed more than either of the other three wells. The quantities for all the wells ranged from 1.8 to 6.1 parts per million.

§ 102. The rate of decrease was quite rapid at first, and while it gradually grew slower, it was quite abrupt at the end. The well alluded to as being in an adjacent plot may serve as an illustration of both the rapidity of the rise and the rate of decrease. On July 4th, before irrigation, and with a low water level, it carried only a trace; on the 9th, after irrigation, and with the water plane near the surface, it carried 475.63 parts per million. In the next two days this fell to 242.0 parts, in the succeeding seven days it fell to 89.74, in seven days more to 35.89 parts, and in seven days more to what may be expressed as within the range of its constant content. This well behaved unlike the others, for while mine showed a temporary increase in nitric acid about August 8th, this one continued to decrease until there was less than 1 part of nitric acid per million.

§ 103. As a rule the nitric acid was lower when the water plane was low, but there were variations which showed no relation to either the height of the water level or to the amount of the total solids present; for instance, the nitric acid in the water of well C on August 1st was 2.5 parts per million, on the 8th 8.4 parts, on the 22d 2.7 parts; the total solids on the 1st were 2.0143 parts per thousand, on the 8th 1.9143 parts, and on the 22d 1.8000 parts. The height of the water table on the 1st was 7.75 feet, on the 8th 7.67 feet, and on the 22d 7.15 feet above the reference plane. The

increase on the 8th was probably due to a rainfall which took place on the 5th and 6th and amounted to 0.78 of an inch. There were also slighter rainfalls on the 1st, 2d, 16th and 17th, but the total of these amounted to only .12 of an inch, the heaviest one was only .07 of an inch, too small an amount to produce an observable influence. The comparatively small rainfall of .78 of an inch seems to have been the cause of the increase of the nitric acid in the ground water, for the increase in the four wells was simultaneous, though quite unequal; the greatest increase being 6 parts per million, the least 1 part per million. The effect of this rainfall was not great enough to show in well E, as the nitric acid was falling at a rapid rate and our samples were not taken often enough to show small variations in the rate of falling.

§ 104. There was a slight change of the water table between the 6th and the 8th, amounting to a few hundredths, the greatest being 0.08 of a foot. The actual distance of the water table below the surface at this time was from 3.0 to 5.2 feet. Under these conditions there can scarcely be a thought of the nitric acid, nitrates, having been added to the ground waters by its direct washing downward through the soil. The wells in which the water was the deepest below the surface showed the greatest increase. This is what we would expect if the rain water simply flowed through the soil, carrying the nitric acid or its equivalent nitrates down with it. This amount of rainfall, 0.78 of an inch, is, however, insufficient to wet this depth of soil. As the surface of this soil was in an almost air dry condition at the time of the rainfall, it was probably not wet to a depth greater than two inches, which is a liberal estimate, but if we put the depth to which the rain water penetrated at four times this estimate, it would not account for the rise in the water table, nor for the washing downward of the nitric acid to a depth of a little more than 5 feet. I think that the oscillation in the water plane and the increase in the nitric acid in the water were both due to the effect of the rainfall upon the capillary conditions of the soil; the nitric acid, more explicitly the nitrates, exhibiting a downward capillary movement.

§ 105. A sample of water taken from well A on December 7, 1898, showed only a trace of nitric acid. This determination was repeated to assure myself that no mistake had been made, but the results were the same, corroborating the first determination. This was the fourth instance that we had met with in which there was only a trace of nitric acid present in the water. These four instances were met with when the water plane was low, but not when it was at its lowest.

§ 106. Well A was located in a portion of the plot where the incrustations formed most abundantly, where the mechanical con-

ditions of the soil were most unfavorable and where the water plane was the nearest to the surface at all times. This last fact may have effected a more regular removal of the nitric acid as it was formed than in the other cases. Whether this is the explanation or not, the water from this well showed uniformly as much nitric acid as that of any of the other wells, though the first two inches of the soil was lower in nitric acid than the corresponding samples from the other sections, but irrigation did not increase the nitric acid in the water of this well as it did in some of the others.

§ 107. Well C is located in the next most unfavorable section and the water level is in round figures 1 foot further below the surface than in well A. The nitric acid varied greatly in the water from this well, and its amount was immediately and greatly affected by irrigation or rainfall, even a light rainfall being followed by a marked increase in the amount of nitric acid.

§ 108. I have said nothing about well G, a shallow well near well A, in connection with the nitrates. This well was separated from the gravel stratum by two feet of soil and was only 12 feet from A. There was no more relation between the quantities of nitric acid in these wells, nor in its variations, than between it and wells farther removed.

§ 109. A careful consideration of the results at my disposal do not justify me in making any comparison or assuming any relation as existing between the nitric acid in the waters of these different wells. There is a general similarity in their conduct, but it is greatly modified by, if not wholly dependent upon, the soil conditions in the immediate neighborhood of the well. Well A, on July 8th, before irrigation, showed the presence of 1.79 parts per million and well G only a trace; on the 11th, after irrigation, A showed 15.2 parts and G 19.2 parts of nitric acid per million; by the 25th inst., the nitric acid in A had fallen to 6.59 parts per million, and in G to 2.69 parts. The water plane was nearly the same in the two wells, it being 0.18 of a foot higher in G than in A.

§ 110. The relation between the amount of nitric acid and the total solids is even less intimate than that of the chlorin to the total solids, which is practically equivalent to stating that there is no relation between them.

§ 111. An examination of the 300 determinations of the nitric acid in this ground water does not permit us to draw any conclusions in regard to the effect of either the physical condition of our soil or of the amount and character of our alkalies upon the formation of nitric acid in the soil. The average of the soil samples taken to a depth of two inches indicates the presence of 469 pounds of potassic nitrate or its equivalent in every acre of soil

taken to this depth, *i. e.*, two inches, which is a goodly supply. Our determinations, however, show that this statement cannot be extended to the second two inches, and much less to the first foot of soil, the conventional depth on which to base such computations. Whatever the effects of our conditions may have been, they were certainly not prohibitive of the production of nitric acid.

§ 112. I can find no examinations of ground waters with which to compare my results. The nitric acid in drain waters is another question, and I shall subsequently, in another bulletin, show that drain waters and ground waters from the same territory are not comparable, so that nitric acid determinations in drain waters are not available for my present purpose. I am compelled by the lack of better data to use samples of another ground water taken by myself as the basis of my statements in regard to the effects of our conditions upon this subject.

§ 113. A sample of ground water from a field lying to the west of my plot, several feet higher, and of an entirely different aspect and character, was taken 10 days after irrigation and showed the presence of 0.718 part of nitric acid per million. This land is in good condition, is not alkalized, water logged, or subject to the adverse conditions obtaining in my plot. The field, however, was in alfalfa at the time the sample was taken, July 5th, and the sample represented the ground water in the soil at that time, for the sample was taken immediately after the hole was dug. The nitric acid in this sample is lower than was usually found in ground water from my plot, but is not so low as was sometimes found in it, but as these smaller quantities are exceptional, it is probably safe to conclude that the ground water in my plot is quite as rich, or even richer, in nitric acid than the average ground water of the neighboring soils.

I did not know, nor even suspect at the time these samples were taken, that I could not compare them with drain waters, nor did I fully appreciate the fact that a sample of water taken from the soil represented so little beyond the conditions prevailing within a very few feet of the point where it was taken.

§ 114. Judging from the amount of nitric acid found in the aqueous extract of the soil, especially in that from the first two inches and from the amount usually present in the ground water as represented by the wells, ranging up to 6 or 8 parts per million, but as a rule from 2 or a little less to 5 parts per million, the alkalized condition was not unfavorable to the formation of nitric acid, The abundance of proteids in the beet crops grown on this ground. they being slightly higher than the average in this respect, also support this view.

§ 115. The great difference in the amount of nitric acid in the first and second two inches of soil, suggested the question of a possible reduction of the nitric acid from some cause. I had no reason to suspect the formation of ferrous salts, and the amounts of ammonia and nitrous acid found in the well and drain waters examined for these constituents did not strongly support the idea of a reduction. The maximum amount of free ammonia found in the well waters before irrigation was 0.0850 part per million, and after irrigation 0.5780 part. The maximum quantity of nitrous acid found in the well waters before irrigation was 0.0837 part per million, and after irrigation 0.1000 part. The increase in the free ammonia present after irrigation is not accompanied by a corresponding increase in the nitrous acid, but is greatly exceeded by the increase in albumenoidal ammonia, so that the probabilities are in favor of another source for it rather than that of the reduction of nitric acid. The nitric acid in these samples was, moreover, quite as high as the average, being 2.692 parts per million before irrigation and 7.628 parts per million after irrigation.

§ 116. When we consider the large amount of nitric acid per acre, 293.14 pounds, existing in the uppermost two inches of this soil, and while the second two inches show less than a tenth as much, and further, that the ground waters are comparatively poor in it after as well as before irrigation, we are forced to the conclusion that there is a tendency in our soil to the concentration of this salt in the upper portions. Whether this is due to a very rapid formation of it at this point, or to the action of capillarity under our meteorological conditions, is an open question. Long continued cloudiness, with or without continued or heavy rains, which means impeded evaporation, is followed by a greater increase in the amount of nitric acid in the ground water than we have observed to be due to irrigation. In fact the increase due to irrigation has in no case been comparable to that observed after long rains. I have no explanation to offer for this fact unless we find one in the difference between the rate at which the nitrates tend to move upward, due to capillarity, whose effects are made more marked by our conditions, almost continuously favorable to a rapid evaporation from the surface and that at which they may be washed downward by the amount of water used. It is well known that the nitrates appear in alkaline crusts under favorable conditions, sometimes forming several per cent. of the mass, but I have not found it present in any incrustation collected in Colorado except in traces.

§ 117. I expected to find relatively large quantities of nitrates n the ground water, owing to the fact that the soil is not usually credited with any great power of retaining them when solutions of these salts are passed through them, and I at first assumed that

there was enough downward moving water in the soil, even when the voids between the soil particles were not completely filled with water to carry the nitrates into the ground water. Such does not seem to be the case, for if it were, the ground water immediately after irrigation ought to be richer in nitrates than they were found to be, even after making liberal allowance for the fact that the irrigation might effect a dilution of the ground water. In the case of the total solids we find a very decided increase, more salts having gone into solution than was necessary to maintain the degree of saturation. This is true, too, of the nitrates, at least in a measure. In the case of the irrigation applied August 31st and September 1st, 1899, the results were not uniform in regard to the increase of the nitrates in the ground water, indeed an increase in their quantity was the exception. This result was probably due to the fact that I had a more liberal supply of water than in any previous irrigation and the results were due to dilution of the ground water, owing to the addition of a large quantity of water in a short time.

NITROUS ACID IN THE GROUND WATER.

§ 118. I have given the limits found for the nitrous acid in the ground water, especially before and after irrigation, in a preceding paragraph. Our examination of the water did not as a rule extend to the determination of this constituent except in studying the effects of irrigation upon the composition of the ground water, off-flow and drainage, under which topic the results observed will be given more fully. The results of the determinations made indicate that as a rule the nitrous acid present in the ground water of this plot was low, not exceeding 0.0837 part per million, except immediately after irrigation, when it rose to 0.1090 part per million. The least quantity of nitrous acid was found in the ground water from the alfalfa field west of our plot, in which we found only a trace.

§ 119. The few samples of drain water which we examined were richer in nitrous acid than the ground waters. The ground waters were richer in nitric than in nitrous acid; while the reverse was the case with the drain waters. The cause of this might be a reduction of the nitrates in passing through the soil to the depth of the drain, which is about four feet, but the ratio of increase above that of the nitrates caused by irrigation suggests that it is rather due to the deportment of the salts of this acid toward the soil particles. For while irrigation did not always increase the nitrates in the ground waters, it always increased the nitrites, and in those cases in which it caused an increase of the nitrates from 1½ to 3 times their previous amount, the nitrites were increased from 8 to 30 or more times. It should be remembered that we always had very much smaller amounts of nitrites than of nitrates to deal with.

The presence of larger quantities of nitrites in the drain than in the ground water is more probably due to the deportment of the solution of these salts within the soil than to a reduction of the nitrates. This view is suggested by the facts stated above, and also by the fact that the off-flow water is poorer in nitrates than the ground water either before or after irrigation, while the nitrites in the off-flow water amounted to more than 200 times as much as was found in the ground water, but the amount was less than that which was found in the drain waters. I do not maintain that there is no reduction of the nitric to nitrous acid taking place in this soil, but simply that the appearance of the nitrous acid in the drain and off-flow water in excess of the nitrates does not necessarily indicate a reduction of the nitric acid, but is probably to be explained in this case by the different deportment of these salts after they have been formed, without regard to the method of their formation. I stated in a former paragraph that I had no reason to assume the formation of ferrous salts or the presence of other conditions favoring the reduction of the nitrates in any unusual degree, micro organisms not included.

AMMONIA IN THE GROUND WATER.

§ 120. The ammonia and ammonia salts in the soil were shown in Bulletin 65 to probably amount to a little more than 0.00211 per cent. of the soil. The amount of these salts in the ground water is small, ranging from 0.0230 to 0.0850 part per million. Irrigation increased this amount to from 0.0570 to 0.5780 part per million. The drain waters were found to contain from 0.0496 to 0.0944 part per million.

§ 121. The albumenoidal ammonia present ranged from 0.0674 to 0.3029 part per million in the ground water and was greatly increased by irrigation. The maximum found after irrigation was 3.1170 parts per million. This kind of ammonia does not pass into the drain very freely; it amounted to 0.2299 part per million in the drain water from this plot. The comparatively small amount of ammonia found in the drain waters strengthen the statement made relative to the reduction of the nitrates to nitrites. The reader may be tempted to think that we intend to discuss the potability of this water. Such is not the case. It is purely a matter of the soil conditions. It is for this reason that certain properties of the water are not discussed at all.

AMOUNT OF NITRATES, ETC., REMOVED BY THE IRRIGATION WATER.

§ 122. The question as to how much of the nitrates, nitrites, and ammonia of both kinds was taken from the soil by the water naturally suggests itself. This question is difficult to answer in regard to the ground water, for there are a number of considerations

entering into the answer which are not known with sufficient definiteness. The same may be true of the off-flow water, but this water is the same that flowed onto the soil, and, after having been in contact with it for a certain length of time, flowing over it for a distance of 600 feet in this case, was collected for examination. The water as it flowed onto the soil contained only traces of nitrates; the first portions that flowed off contained 1.970 and 1.077 parts per million respectively; the last portions that flowed off contained 0.3590 and a trace respectively.

§ 123. The ground water in two instances showed an increase in the nitrates from 1.970 and 2.513 to 3.231 and 7.628 parts per million respectively. In two other instances a slight decrease was observed.

§ 124. The rapid diminution in the amount of the nitrates removed by the off-flowing water shows that their removal by the water flowing over the soil is very limited, probably confined to the very surface of the soil. In this connection I would recall the fact that comparatively large quantities of nitrates existed in the upper two inches of this soil. It is evident that the water upon coming in contact with the soil wets the uppermost portion before flowing over it; this takes place even when there is a good head of water. This wetting means a downward movement of the water at first, which may carry the nitrates not somewhat firmly held by the soil, down into the soil and beyond the action of the succeeding, overflowing portions of water.

§ 125. It is stated above that two instances of a decrease in the nitric acid were observed after irrigation. This decrease was in wells B and D and amounted to 0.1840 and 1.0870 parts per million respectively. In the case of D, which was near the point at which the water was brought onto the plot and where the soil was a sandy loam, it may be that the irrigation water may have found its way into the well more directly than it was intended it should, or it may be that the amount of water received at this point sufficed to produce leaching, but I am very doubtful of this.

§ 126. The water, especially the ditch water, used for irrigating, contained an unusual amount of nitrous acid. Whence it came I did not attempt to ascertain, and it was probably not true of the water after it had been running for some hours. Some of the water used was what we designate as seepage water, and contained 0.2340 parts nitrous acid per million. The off-flow was from 3 to 8 times as rich in nitrous acid as the ground water after irrigation. The amount of the off-flow was comparatively small. What relation it bore to the amount applied, I did not determine, nor have I any means of estimating how long the water collected was in contact

with the soil. No account has been taken of the amount of water evaporated, which was probably a larger fraction of the water applied than we would think, possibly not less than a sixteenth of it. The rate of evaporation from a standard tank at the time this irrigation was made was 6 inches in 30 days, and as our irrigation extended over 3 days, the evaporation probably amounted to fully .6 of an inch.

It required about 34 hours for the water to flow the length of the plot, 600 feet, and produce an off-flow. The first samples of the off-flowing water were taken soon after the off-flow began, and the second samples were taken 8½ hours later. At this time the off-flow was estimated to be about half of the on-flow.

§ 127. The albumenoidal ammonia in the ground water was materially increased in two of the wells, but in the other two wells its amount was affected in a very much less degree. The off-flowing water was only slightly richer in this kind of ammonia than the on-flowing water.

§ 128. The rate at which the water flowed over the ground and also the rate at which it passed into the soil probably exerted an influence upon the amount and kinds of salts taken into solution. An attempt was made to determine the rate at which the wells filled; they were measured, pumped down, remeasured, and the time noted which was required for them to fill again. The rate varied with the soil and other conditions, but our results indicated an inflow of from 7 to 11 cubic inches per minute, the water outside of the wells standing from 24 to 36 inches above the surface at the beginning of the experiment. This does not indicate so rapid a draining out of the water from a comparatively free surface as I expected. The surface varied in the different wells, but this requires nearly 30 square inches to furnish one cubic inch of water per minute, or a square foot yielded at the rate of 4.8 cubic inches per minute. No attempt was made in this crude experiment to find out how much space about the well was affected by the lowering of the water in the well; it was very small at best. This rate of inflow would have diminished materially after a short time. I have elsewhere stated that the lateral movement of the solutions, which may be quite equivalent to water, is very small, if not zero, in this plot, for the amount and kinds of salts in the water in wells near to one another are different and maintain their individuality throughout a series of changes in the conditions of the ground water, including the effects of irrigation. The rate of the flow into the wells does not seem to be sufficiently high to disturb the relation of the well water to the ground water to such an extent as to demand special consideration. The differences between the ground waters and aqueous extracts of the soil already noted are not sensibly affected by the lat-

eral passage of the solutions through the soil and probably not by their downward movement in the plot under discussion. If the conditions were changed, for example, by judicious and thorough drainage, then the question of alkali salts in the soil would be one of time and the amount of water applied to the surface. Our object from the beginning was not to study the effects of drainage as such, but the effects of cropping and cultivation where irrigation is necessary but drainage difficult or impossible.

SUMMARY.

1. The question of alkalization in Colorado resolves itself into a question of drainage.

2. Alkalization in this state has been made more apparent, and its effects increased, by over irrigation.

3. Crops growing on alkalized soil with the water table quite near the surface were sensitive to drouthy conditions.

4. The water plane is 1.83 feet higher at the west end of the plot than at the east end and the drainage is probably to the eastward.

5. The inclination of the water plane to the eastward is less than that of the surface.

6. The height of the water plane often changes without sensible cause, probably due to atmospheric conditions, pressure, temperature, etc.

7. Light rains during dry periods produce, as a rule, comparatively great increases in the height of the water plane, probably due to modification of the capillary conditions.

8. Light rains during an interval of abundant moisture when the soil is wet do not produce an increase in the height of the water plane.

9. Moderate rains were sometimes accompanied by temporay depression of the water plane. This was accounted for by the rate of rain fall, character of soil and the air contained therein.

10. The effect of an irrigating ditch running past the east end of the plot was to raise the height of the water plane by 0.30 of a foot at a distance of 142 feet from the center of the ditch. This raise was apparently produced by the causing of a backward pressure and not by direct infiltration of water.

11. When the water plane rose due to changes in capillary conditions caused by light rain falls it usually fell to its former level in about three days, but when it rose after an irrigation it required from 10 to 13 days for its fall.

12. The total solids, salts held in solution in the different well waters,

varied both in quantity and in the ratio of the different salts present. Their amount and character depended upon the conditions obtaining in the immediate vicinity of the well.

13. The total solids rose and fell with the water plane, passing into the water as it rose, and remaining in the soil when it fell. This is the same as saying that the total solids in solution depend upon the relative masses of the water and soil and vary with the character of the soil, including the salts retained in it. The preceding is a general statement and does not consider the irregular increase or decrease of the total solids in the same well at different times. These are unquestionably dependent in a large measure upon the unlike conditions of chemical equilibrium obtaining in the solution at different times.

14. The increase in the amount of total solids in a well water is not always the greatest in those wells which show the greatest rise in the water plane, nor in those which usually show the greatest quantities of total solids. The increase in the total solids due to the rise of the water plane seems to be partly dependent upon the rate of diffusion through the soil.

15. The height of the water in the different wells was essentially the height of the water table in the soil.

16. The total solids in the well waters were less than in the water in the soil. This difference was not due to a mixture of water entering the wells from different sources, but was seemingly due to the modification of the laws of diffusion and solubility by the soil itself.

17. The total solids in the ground water were lower in 1899 than in 1897 as indicated by samples of ground water taken 10 days after irrigation.

18. The chlorin, or its corresponding salt, sodic chlorid, was at no time very abundant in the ground water and bore no definite relation to the total solids, as the sodic chlorid ranged from 5 to a little more than 14 per cent. of their total weight. The increase or decrease of sodic chlorid, common salt, was not proportional to the increase or decrease of the total solids and did not serve as an index of either the amount of total solids present or of their variation, except within very wide limits.

19. The chlorin may not always be present in the form of sodic chlorid, which is tacitly assumed in the preceding statement. Analytical results indicate that it may sometimes be present as magnesic chlorid, and the irregular deportment of chlorin in the waters may be due to such causes, *i. e.*, differences in the manner of its combination.

20. The chlorin present in the ground waters and its variations in quantity throw but little or no light upon the movement of the alkali salts within this soil.

21. The term total solids is equivalent to the salts constituting the free solution in the soil. The term represents a different mixture of salts than is found in the incrustations forming on the surface of the soil, or obtained by evaporating an aqueous extract of the soil to dryness.

22. The total solids in the ground water varied greatly in the different wells, and also from time to time, in regard to their quantity, but only to a limited extent in their chemical composition. The difference in the latter respect was almost exclusively confined to the relative quantities of the respective salts.

23. The method of combining the analytical results has been adopted as convenient and probable, but not as infallible.

24. In combining up the analyses there is frequently a slight excess of sodic oxid, this is often within the limits of analytical errors, at others it is rather high. We have observed that this excess is usually higher when the loss on ignition is high and are inclined to attribute it to the presence of organic acids.

25. The alkali incrustations from this plot consist essentially of sodic

and magnesic sulfates in the ratio of two to one; they together constitute 80 per cent. of the mass. Calcic sulfate is subordinate in quantity with sodic chlorid and carbonate still more so.

26. The salts dissolved in the ground water, the total solids, consist much more largely of calcic sulfate than of sodic sulfate, and contain about the same amount of magnesic sulfate as the incrustation from this plot. The ratio of calcic sulfate to the magnesic and sodic sulfates in the total solids is approximately 2:1¼:1.

27. The salts extracted from the first two inches of the soil by continued treatment with water consisted of the same salts, they made up nearly 80 per cent of the total, but the ratio was approximately 4:2:1.

28. The aqueous extract of the second two inches of soil contained very little magnesic sulfate, no sodic sulfate, and almost 51 per cent. of calcic sulfate. This extract showed a large amount of soluble silicic acid, corresponding to 14.5 per cent. of sodic silicate calculated on the dried residue.

29. The upper portions of the ground water are richer in total solids than the successively deeper portions and the salts in solution differ, especially in their relative quantities.

30. There seemed to be an abundant formation of nitric acid in the upper portions of the soil, even in portions of the plot where the alkali salts were abundant.

31. Nitric acid occurred so generally in the ground waters and its variations were so dependent upon other conditions that we cannot judge of the effect of the alkalies present nor of that of the mechanical conditions.

32. There was no relation between the amount of total solids and that of the nitric acid present.

33. There was no relation between the different wells in regard to the quantity of nitric acid present or its variations.

34. Irrigating the ground increased the nitric acid in the well waters, so did even light rainfalls, probably due to increase of capillary exchange of the nitrates between the upper portions of the soil and the ground water.

35. The ground water from this plot is richer in nitrates than that from neighboring land which is in better condition.

36. The nitrites in the ground water are relatively high and are increased by irrigation. This is probably due to the biological conditions of the soil and the deportment of solutions of nitrites toward the soil, especially in regard to the readiness with which they will pass through it.

37. The free ammonia and ammonia salts were not especially abundant in the ground water, either before or after irrigation, though more abundant after than before.

38. The ground water was slightly richer in free ammonia than the drain water from this plot.

39. The albumenoidal ammonia in the ground water was not excessively high, but it was materially increased by irrigation. The albumenoidal ammonia did not appear to pass freely into the drain water.

40. The amount of nitrates removed by off-flow water is probably quite limited as their quantity in the off-flow diminished rapidly.

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Bulletin 73. August, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

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FEEDING BEET PULP AND SUGAR BEETS TO COWS.

—BY—

B. C. BUFFUM and C. J. GRIFFITH.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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THE FEEDING VALUE OF BEET PULP AND FEEDING BEET PULP AND SUGAR BEETS TO COWS.

BY B. C. BUFFUM AND C. J. GRIFFITH.

PART I. INTRODUCTION.

The natural conditions in arid America where a comparatively small part of the land is reclaimed by irrigation and the rest will always be used as range for live stock, make the stock industry one of the most important features of our Agriculture. With the development of our irrigated farms has come smaller holdings of better classes of stock than those originally pastured on the ranges, and the farmer has become desirous of finishing his stock for market at home instead of selling feeders to be fattened in the corn growing states east of us.

The growing of alfalfa on our farms to supply a rotation which will keep up the fertility of the soil has become an indispensible practice and this surplus hay is an important item of profit if it can be fed at home.

Establishing the beet sugar industry has brought to our farmers another source of stock foods in the by products of the sugar factories, the most important of which is the beet pulp which is left after the sugar has been extracted. The coming winter we estimate that the factories now established in the state will produce over 150,000 tons of this pulp which will be available for feeding stock. Our farmers are customers for large quantities of corn shipped in from Kansas, Nebraska and Iowa, for which they pay large prices in order to enable them to profitably use their alfalfa in fitting stock, more especially lambs, for market. Anything which will make our own people more independent by producing their own feeds instead of purchasing from abroad is of inestimable value to the state. The Experiment Station is continually trying to solve this problem and furnish the information it may gain to those who can make use of it. The feeding value of sugar beets and of beet pulp, the comparative value of our home grown grains, and corn and of such new grains or new stock foods of whatever nature, and the combinations of these foods which will give the largest returns, are important questions which have been receiving marked at-

tention recently. We are now ready to publish bulletins giving the results cf a series of experiments which have been carried out to throw light on these questions. An experiment has been carried out on the sub-station at Rockyford by Mr. Griffin, to show the value of beet pulp combined with alfalfa for lamb feeding. In the present bulletin we give a brief resume of the value of beet pulp as determined in other places and report some trials in which beets and pulp were fed to cows on the College farm at Fort Collins. The information of the value of pulp as determined in other places has been gleaned from every available source which we have reason to believe is reliable and in connection with our own investigations will give our farmers and stockmen some basis upon which to decide whether or not it will pay them to feed pulp to their stock. In addition to this bulletin, we have ready for publication a bulletin on "Swine Feeding in Colorado" which reports trials with beets and pulp and which gives the only information we know of about the value of beet pulp for hog feeding, and also a bulletin entitled "Lamb Feeding Experiments in 1901-1902," in which will be reported the results of our trials of pulp and beets in rations for fattening lambs. We speak only of the diffusion pulp such as comes from our factories.

COMPOSITION OF BEET PULP.

Professor Henry in his book "Feeds and Feeding" gives the result of sixteen analyses and seven trials of digestibility of beet pulp, which shows the following composition. The digestible nutrients are given:

BEET PULP. AVERAGE OF 16 ANALYSES.

Dry Matter.	Protein.	Carbohydrates.	Ether Extract.	Nutritive Ratio.
10.2	0.6	7.3	—	1:12.2

Analyses made by the California Station, published in their bulletins, show a nutritive value considerably higher than the above. These analyses also show the comparative value of beet pulp, pulp silage and sugar beet silage.

The digestible nutrients only were calculated.

CALIFORNIA BEET PULP.

	Water.	Protein.	Carbohydrates.	Fat.	Feed Value Calories.	Nutritive Ratio
Beet Pulp	90	1.25	8.19	0.14	164	1:6.7
Beet Pulp Silage	90	1.46	7.84	0.39	165	1:5.7
Sugar Beet Silage	70	4.38	23.52	1.17	351	1:7.7

Analyses made by Dr. Headden, Professor of Chemistry

at the College, shows our Colorado pulp to have the following composition:

COLORADO BEET PULP.

Dry Matter.	Protein.	Carbohydrates.	Fat.	Nutritive Ratio
10.0	0.38	7.36	0.2	1:20.5

The crude fibre and nitrogen free extract were reported separately but we combine them under carbohydrates. According to the Calfornia analyses, the beet pulp silage has a narrower ratio and a little higher food value than the fresh pulp, which seems to be the general experience in practice. It will be noted that the fresh pulp is apparently worth between one-third and one-half as much as the sugar beet when made into silage.

The places are not given where the analyses reported by Henry were made; possibly they were all from Europe, and if so, it is possible that the diffreence between the beet pulp there and in this country would be as great as that shown. The analysis given in the Report of the United States Department of Agriculture as an average analysis, is about midway between the ones given above.

The nutritive ratio from the analysis is given as 1:7.2, which it is pointed out, is near the standard ratio for a fattening steer, according to the given standard.

The analysis of the Colorado pulp gives a lower amount of protein and a little more carbohydrates and fat than the composition as given by Professor Henry. This makes the nutritive ratio correspondingly wide.

RESULTS OF FEEDING TRIALS.

EUROPE.

Some experiments in feeding pulp in Europe as given in the year book of the U. S. Department of Agriculture for 1898 are of especial interest to us, as the roughage used was alfalfa hay, the ration being enriched by using linseed oil-cake. The following table presents these results. The value per ton of pulp is computed from increase in weight and value of other foods given.

ANIMALS.	FEED.				
	Pulp. lbs.	Alfalfa. lbs.	Linseed Cake. lbs.	Grain per Day. lbs.	Value of Pulp per Ton.
Beef Cattle	115.0	6.6	6.6	2.214	$1.18
Oxen	126.8	12.0	2.2	——	0.87
Sheep	11.8	1.1	0.44	0.3	1.58
Ewes	——	——	——	——	1.10
Average					$1.18

It was stated that the oxen fell off in flesh the first fifteen days on pulp, but after that they gained and did more work on the pulp ration. The ewes were given a little larger ration than the sheep. An experiment in feeding milk cows was said to be even more satisfactory but the comparative value of the pulp was not indicated.

CALIFORNIA.

The California Experiment Station has published some general statements regarding the value of pulp. Different stockmen replied that they could afford to pay from 25 cents to $1.00 per ton for beet pulp. One man placed the value of fermented pulp at 25 cents per ton more than fresh pulp. The pulp there is fed with oat and barley hay and straw, along with chopped grain and cottonseed meal. It is claimed that the meat dresses whiter and with less sinews when fed pulp. An experiment is reported in which pulp was fed to cows and its effect on feed consumed, milk flow and butter fat noted. An accurate account of the hay was not kept, but approximately when no pulp was fed, the cows consumed twenty pounds of hay per day, in addition to eight pounds of grain. When given pulp, the consumption of hay varied from 6 to 16 pounds, depending upon the amount of pulp, which varied from 20 to 80 pounds per day. The effect on the milk flow was beneficial, but there was no appreciable effect in raising or lowering the proportion of fat in the milk.

MICHIGAN.

The Michigan Experiment Station has carried out some interesting experiments in feeding beet pulp. In one experiment pulp was fed to steers at the rate of 55 pounds per day along with mixed hay, shredded corn stover and ground grain. The amounts of foods given and eaten were compared with a check lot not given pulp. It was found that one ton of pulp took the place of 421.5 pounds of corn stover, 274 pounds of mixed hay and 68.8 pounds of grain. At Colorado prices of $4.00 per ton for the roughage and 1¼ cents per pound for the grain, this would give the pulp a value of $2.25 per ton.

In another experiment 13,775 pounds of pulp gave an increased gain of 280 pounds of beef. Giving the increased gain a value of 7½ cents per pound would indicate that the feeding value of the pulp was a little more than $3.00 per ton.

Experiments with milk cows showed that the pulp, when given with hay and grain, increased the flow of milk some-

what but did not add to the yield of butter fat. This report states that owners of growing and fattening cattle declare that pulp saves one-third of the coarse fodder.

NEW YORK.

The Cornell Station reports experiments in feeding beet pulp to cows. Their conclusions are as follows:

"The cows, as a rule, ate beet pulp readily and consumed from 50 to 100 pounds per day, according to size, in addition to the usual feed of 8 pounds of grain and 6 to 12 pounds of hay."

"The dry matter in beet pulp proved to be of equal value, pound for pound, with the dry matter in corn silage."

"The milk producing value of beet pulp as it comes from the beet sugar factory is about one-half that of corn silage."

"Beet pulp is especially valuable as a succulent food, and when no other such food is obtainable it may prove of greater comparative value than is given above."

In the dairy districts of New York and other states where factories have been established, beet pulp is coming into great demand for cows.

NEBRASKA AND OTHER PLACES.

In New Mexico, sheep, and in Utah, cattle, have been successfully fattened and put on the market with no other food than pulp and alfalfa hay.

In Nebraska some valuable data has been obtained with both sheep and cattle. . Experience there indicates that a maximum amount of 40 or 50 pounds pulp per day for each steer gives better results than larger amounts. Mr. John Reimers, whose report on pulp feeding has been often quoted, states that cattle eat the same amount of hay and grain when given only moderate amounts of the pulp, but that they lay on flesh more rapidly, shortening the feeding season, and that the pulp gives extra gains of from 50 to 75 pounds in three-fourths of the usual time, which results in a great saving of grain and roughness. His pulp-fed cattle dressed and shipped as well as any other, even for export. Many general reports have been made by those who have fed this important by-product of the sugar factories and all testify to its value both for fattening and the production of milk.

In Colorado some extensive feeding has been done with with pulp. Several feeders in the Arkansas Valley have fed large quantities to both sheep and cattle during the past two years. Col. J. A. Lockhart at Rockyford fed 3,700 head of

cattle during the past winter using beet pulp, alfalfa hay, sorghum, cotton seed meal, corn and bran. He has kindly offered to furnish the Station with his results, and as the feeding was done on so large a scale the data obtained will be very valuable. Mr. Rhodes, of Las Animas, fed 2,200 lambs on pulp, and speaks very highly of the pulp. There was practically no loss of lambs, they made large gains, and he states that the saving of hay while they were receiving the pulp was very marked. Several feeders at Loveland, Colorado, who fed pulp last season will feed on a larger scale the coming winter. Mark Austin, the Agricultural Superintendent for the Loveland Sugar Factory, profitably fed lambs and cattle, and Wm. Davis, a farmer north of Loveland, tells us that his cattle did exceeding well on the pulp ration.

USE OF PULP.

It should be stated that the attempts to compute the cash value of pulp compared with other foods do not indicate its total value. It supplies a succulent food at a time when such food is either not available or is scarce, and its effect on stock seems to be much more favorable than either its chemical analysis or the return in increased meat or milk would indicate. To its actual nutritive effect as a food should be added its general effect on the quality of meat and milk and on the animal system. Pulp undoubtedly overcomes much injurious effects of dry and concentrated foods, puts the system in good sanitary condition, keeps off disease, and so aids the appetite and digestion and assimilation of food that there is less waste, both of food which is generally discarded in eating, and that which usually passes through the animal undigested.

There seems to be no difficulty in regard to keeping beet pulp. While there is some loss of material when placed in open piles, the fermentation which takes place seems to be beneficial rather than otherwise. Animals eat the sour pulp as well, and after a little time even better than they do the pulp fresh from the factory, and the dry beet chips on the surface of the piles are very palatable to sheep and cattle. Nebraska feeders claim that pulp which has been left in open piles for two or three years is as good as ever.

No injurious effects have been observed from feeding pulp, unless too large amounts are given before the animals become accustomed to it. The Michigan Station warns feeders against too liberal use of pulp from frozen beets. Freezing does not seem to injure the pulp itself, except that it

probably does not pay to feed large amounts of frozen pulp in cold weather, as the animal must expend much food energy to raise the temperature of the pulp to the heat of the body. Utah reports a case of the pulp becoming poisoned in shipping. The pulp was shipped in freight cars which had been used in shipping lead ores from the mines, and the pulp absorbed enough of the lead to make it dangerous to stock.

During the past spring the Denver papers gave an account of cattles' mouths becoming sore from eating pulp, claiming that the injury was produced by acids added to the pulp in the process of manufacture. This is hardly possible, as the pulp is subjected to nothing but hot water at the factory. Through the process of fermentation from long keeping butyric and acetic acids develop in pulp, but we have no accounts of any injurious effects from feeding fermented pulp.

The greatest difficulty with pulp feeding is that the large amount of water it contains makes it heavy and rather expensive to handle, and it is sometimes difficult to keep the animals dry and comfortable while feeding large amounts of it. The feeder who is near the factory and has the appliances so arranged that he can handle the pulp with the least expense, should make the greatest use of pulp and will gain the greatest profit from its use. If it can be placed before stock at a cost of not more than one dollar per ton, we believe it will bring good returns for the investment, and in many instances it may be worth two or three times this amount. Whether fresh, fermented, or dry, beet pulp is a valuable stock food, and one of which our farmers should make the largest possible use.

As an example of how pulp may be combined with other foods in forming a ration, we give the following illustration:

RATIONS WITH BEET PULP.

FATTENING CATTLE WEIGHING 1,CCO POUNDS.

FIRST PERIOD.

		Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Standard Ration		30	2.5	15.0	0.5	1:6.5
Alfalfa	15 lbs.	13.7	1.65	5.94	0.18	
Beet Pulp	75 "	7.6	0.45	5.47		
Cotton Seed Meal	2 "	1.8	0.75	0.3	0.24	
		23.1	2.85	11.71	0.42	1:4.4

SECOND PERIOD.

		Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Standard		30	3.0	14.5	0.7	1:5.4
Alfalfa	15 lbs.	13.7	1.65	5.94	0.18	
Beet Pulp	25 "	2.5	0.15	1.8		
Cotton Seed Meal	2 "	1.8	0.75	0.3	0.24	
Corn Meal	6 "	5.36	0.46	4.0	0.26	
		23.36	3.01	12.04	0.68	1:4.5

The larger part of the above information has been gleaned from the following authorities:

Colorado Experiment Station Bulletin No. 46.
Cornell Experiment Station Bulletin No. 183.
California Experiment Station Bulletin No. 132.
Michigan Experiment Station Bulletin No. 193.
Yearbook U. S. Department of Agriculture 1898.
Special Reports, Division of Chemistry, U. S. Department of Agriculture, 1897, 1898, 1899.
Utah Experiment Station Bulletin No. 74.

FEEDING BEET PULP AND SUGAR BEETS TO COWS.

PART II. INTRODUCTION.

The experiments here reported were among the first planned to compare the feeding value of sugar beets and pulp from beet sugar factories. The value of roots to furnish succulent food during the winter when green pasture is not available, has long been well understood, and such succulent foods are considered especially desirable for cows producing milk. The pulp has a smaller nutritive value than beets because the sugar and salts which have been extracted at the factory are important food products, but there is no question about its succulence. Fresh pulp contains about ten per cent more water than beets. If the office of roots in a ration is to supply juicy foods which will aid in the digestion and assimilation of the roughage and grain fed with it, rather than for the nutritive effect, we would expect pulp to possess the necessary qualifications. The manufacture of silage from corn and other roughage is done to extend the summer conditions of green food through the rest of the year when the animal's system is apt to become clogged with dry grain and dry hay to such an extent that the digestive tract does not perform its normal function.

That the main use of roots or beet pulp is to prevent mal-nutrition and insure general health, rather than to supply food, can hardly be questioned. Food nutrients can be supplied in concentrated form, but in order for the animal to make use of them he must be given bulk to fill up and distend the digestive organs, and the food must be porous and permeable by the digestive fluids. Laplanders eat infusorial earth, which is simply a chalky soil, to help fill up the stomach and dilute the whale blubber which is almost pure fat and forms the chief part of their diet.

Beets or beet pulp given our farm animals supply quantities of tender living plant cells which are filled with juices and which dilute, soften and separate the particles of dry hay and grain so the nutritive qualities of the whole may be more efficiently digested and absorbed out of the mass. This is aptly illustrated by a statement made to one of us by a feeder of long experience. He stated that one winter he followed the usual practice of running hogs with his steers to

consume the undigested corn. The hogs did usually well until he added the beet pulp to the corn ration for the steers, when they so thoroughly digested the corn that the hogs starved and he was forced to give them other food.

Both beets and pulp have nutritive values, that of the beets being greater than that of the pulp. They contain so much water which is merely bulk, that a cow would hardly be able to eat enough of the pulp, at least if given no other food, to supply her maintenance, and there is a limit to the amount of such foods which can be profitably used. Some experiments report cows eating as much as 120 pounds of pulp daily, or forty to sixty pounds of beets. However, excessively large amounts of beets are dangerous, as they contain small amounts of a poison principle which may cause the death of the animal by paralysis, if indeed the mere amount of food does not produce other serious troubles. In all of our experiments up to this time we have confined the amount of beets or pulp fed to a minimum, giving only such quantities as experience in other places has indicated could be fed with profit. We think fifty pounds of beet pulp, or one-half that amount of beets, would be a maximum to add to a ration fed to cows, and in our experiments to show comparative values we have fed approximately one-half as much.

If the main use of beets or pulp is to furnish a tonic or to produce a salubrious mechanical effect, rather than to supply nutriment, then we would not expect to find a great amount of difference in their feeding value when added to grain and hay rations in small amounts. These points should be borne in mind when comparing the results obtained in the following reports of our feeding trials.

The beets fed were grown on the College farm and contained from twelve to seventeen per cent of sugar. The pulp was kindly furnished for the purpose of making the tests by Mr. A. V. Officer, manager of the Loveland Sugar Factory. The pulp was placed in piles on the ground outdoors and fed as wanted.

PLAN OF THE EXPERIMENT.

At first four cows were put on alternate beet and pulp rations, records of which were kept for eleven weeks. Later a fifth cow, Bessie Geneva 2d, was added and fed from the eighth to eleventh weeks. Having obtained five common stock cows before the supply of pulp was exhausted, they were fed in the same manner the last three weeks.

The first week all the cows were given sugar beets; the next two weeks the beets were discontinued and pulp fed;

the fourth and fifth weeks beets were given instead of pulp; the sixth and seventh weeks pulp was fed; the eighth and ninth weeks, beets, and the tenth and eleventh weeks, pulp. The cows were all fed the same amount of hay and grain daily throughout the experiment. The grain was equal parts of corn chop and wheat chop.

There was a slight variation the first week in the amount of grain fed, as the cows were given four pounds of grain per day the first two days, at the end of which time it was increased to eight pounds per day. The first week each cow ate 14.3 pounds of alfalfa per day, and for the remaining time they ate 20 pounds per day. The sugar beets eaten amounted to eight pounds per day during the first week, and twelve pounds per day during the subsequent alternate periods of two weeks each. They ate 24 pounds of pulp daily when given the pulp ration. The rations were as follows:

BEET RATION.

Corn chop, 4 pounds.
Wheat chop, 4 pounds.
Alfalfa hay, 20 pounds.
Sugar beets, 12 pounds.

PULP RATION.

Corn chop, 4 pounds.
Wheat chop, 4 pounds.
Alfalfa hay, 20 pounds.
Beet pulp, 24 pounds.

It is interesting to note how nearly the above rations correspond in digestible nutrients with the theoretical standard for a thousand pound dairy cow giving 22 pounds of milk daily.

	Dry Matter.	Protein.	Carbo-hydrates.	Ether Extract	Ratio.
Standard	29	2.50	13.0	0.5	1:5.7
Our Beet Ration	27.1	3.05	14.6	0.5	1:5.1
Our Pulp Ration	27.8	2.99	14.2	0.48	1:5.1

RESULTS OF THE FEEDING TRIALS.

Tables I to X give the individual records of each of the cows which were fed either beets or pulp for two or more weeks, and Tables XI and XII give in condensed form the records of the five cows which were fed beets one week and pulp two weeks. The minus sign before numbers in columns headed "gain" means a loss of weight for the time indicated.

TABLE I.

DAINTY NOBLE—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
1st.	lbs. 800	lbs. 820	lbs, 20	lbs. 56	lbs. 118.0	lbs. 6.46	4.65
4th and 5th.	820	870	50	168	244.2	13.91	4.87
8th and 9th.	890	830	—60	168	244.5	14.59	5.12
Total.			10	392	606.7	34.96	
Average Weekly.			2	78 5	121.3	6.99	4.88

TABLE II.

DAINTY NOBLE—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
2d and 3d.	lbs. 820	lbs. 820	lbs. 0	lbs. 224	lbs. 246	lbs. 13.89	4.85
6th and 7th.	870	890	20	336	242.2	13.34	4 72
10th and 11th.	830	880	50	336	252.5	15.17	5.16
Total.			70	896	740.7	42.40	
Average Weekly.			11.7	149.3	123.5	7.06	4.89

TABLE III.

GILDANA—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
1st.	lbs. 930	lbs. 931	lbs. 1	lbs. 56	lbs, 59.0	lbs. 3.19	4.60
4th and 5th.	960	970	10	168	144.2	8.15	4.84
8th and 9th.	960	970	10	168	133.0	7.80	4.93
Total.			21	392	336.2	19.14	
Average Weekly.			4.2	78.5	67.2	3.83	4.79

TABLE IV.

GILDANA—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
2d and 3d.	lbs. 931	lbs. 960	lbs. 29	lbs. 224	lbs. 136.5	lbs. 7.6	4.79
6th and 7th.	970	960	—10	336	121.7	7.03	4.95
10th and 11th.							
Total.			19	560	258.2	14.63	
Average Weekly.			4.7	140	64.5	3.66	4.87

TABLE V.

YOUNG GRANNIE—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets	Milk	Butter	Percent
	Beginning	End	Gain	Eaten			Fat
1st.	lbs. 1070	lbs. 1060	lbs. —10	lbs. 56	lbs. 91.5	lbs. 5.28	4.95
4th and 5th.	1090	1080	—10	168	210.5	12.52	5.10
8th and 9th.							
Total.			—20	224	302.0	17.80	
Average Weekly.			—6.6	74.7	100.7	5.93	5.02

TABLE VI.

YOUNG GRANNIE—FED BEET PULP.

Week.	Weight of Cow.			Pulp	Milk	Butter	Percent
	Beginning	End	Gain	Eaten			Fat
2d and 3d.	lbs. 1060	lbs. 1090	lbs. 30	lbs. 224	lbs. 203.2	lbs. 11.68	4.94
6th.	1080	1108	28	168	104.5	5.98	4.89
Total.			58	392	307.7	17.66	
Average Weekly.			19.3	134	102.6	5.88	4.91

TABLE VII.

MOUNTAIN BEAUTY—FED SUGAR BEETS.

Week.	Weight of Cow. Beginning	End	Gain	Beets Eaten	Milk	Butter	Percent Fat
1st.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
4th and 5th.	970	970	0	168	163.0	7.07	3.51
8th and 9th.	1000	1030	30	168	190.2	7.71	3.47
Total.			30	336	353.2	14.78	
Average Weekly.			7.5	84	88.3	3.69	3.49

TABLE VIII.

MOUNTAIN BEAUTY—FED BEET PULP.

Week.	Weight of Cow. Beginning	End	Gain	Pulp Eaten	Milk	Butter	Percent Fat
2d and 3d.	lbs. 960	lbs. 970	lbs. 10	lbs. 224	lbs. 146.7	lbs. 6.43	3.72
6th and 7th.	970	1000	30	336	178.2	7.43	3.57
10th and 11th.	1030	990	—40	336	192.0	7.65	3.43
Total.			00	896	516.9	21.51	
Average Weekly.			00	149.3	86.1	3.58	3.57

TABLE IX.

BESSIE GENEVA 2d—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
8th and 9th	lbs. 1290	lbs. 1260	lbs. —30	lbs. 168	lbs. 519.7	lbs. 28.16	4.59
Total.							
Average Weekly.			—15	84	259.8	14.08	4.59

TABLE X.

BESSIE GENEVA 2d—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
10th and 11th	1260	1220	—40	336	557.2	27.23	3.91
Total.							
Average Weekly.			—20	168	278.6	13.61	3.91

TABLE XI.

FIVE COWS ON BEETS.—NINTH WEEK.

Cow.	Weight. Beginning	End.	Gain.	Beets Eaten.	Milk.	Butter.	Percent Fat.
Brindle No. 3.	lbs. 850	lbs. 860	lbs. 10	lbs. 84	lbs. 210.7	lbs. 9.78	3.96
Black Cow.	990	1030	40	84	255.5	12.86	4.38
Red Cow.	880	890	10	84	180.5	8.78	4.11
Brindle.	1030	1040	10	84	234.2	12.68	4.12
Old Spot.	860	870	10	84	170.7	8.10	4.01
Total.			80	420	1051.6	52.20	
Average Weekly Per Cow.			16	84	210.3	10.44	4.12

TABLE XII.

FIVE COWS ON PULP.—TENTH AND ELEVENTH WEEKS.

Cow.	Weight. Beginning	End.	Gain.	Pulp Eaten.	Milk.	Butter.	Percent Fat.
Brindle No. 3.	lbs. 860	lbs. 800	lbs. —60	lbs. 336	lbs. 465.5	lbs. 20.00	3.70
Black Cow.	1030	990	—40	336	529.0	23.33	3.75
Red Cow.	890			336	376.5	19.13	4.18
Brindle.	1040	935	—105	336	470.7	24.04	4.24
Old Spot.	870	820	—50	336	396.0	18.33	3.95
Total.			—255	1680	2237.7	104.83	
Average Weekly Per Cow.			—32	168	223.8	10.48	3.96

DAINTY NOBLE.—TABLES I AND II.

Dainty Noble is a registered Jersey heifer. At the time of this experiment she was in her first period of lactation, her calf having been dropped January 1, 1902, at which time Dainty Noble was twenty-one months old. Her calf was taken away immediately after birth. Dainty Noble was fed liberally with a ration of wheat and corn chop and alfalfa hay. Sugar beets also formed a part of the ration most of the time until the experiment began, so the beets were not altogether a new food for her, and there would be no undesirable results from change of food ration.

GILDANA.—TABLES III AND IV.

Gildana is an old decrepit Jersey having passed the useful years of her life and is being kept as a nurse cow for unfortunate calves from our beef herds. Gildana's last calf was dropped in August, 1901, from which time she had been milked as her motherly services had not been required elsewhere. She too had been fed sugar beets along with a grain and alfalfa ration. The largest milk record which Gildana leaves is from January 1, 1897, to January 1, 1898, during which time she produced 7,809 pounds of milk. The per cent of butter fat is not recorded.

YOUNG GRANNIE.—TABLES V AND VI.

Young Grannie had dropped her sixth calf in August, 1901, being herself eleven years old the previous May. In her prime she had been a good milker and a large profit cow. Young Grannie is also a registered Jersey. The ration of sugar beets, wheat and corn chop and alfalfa hay had also been fed to Young Grannie.

MOUNTAIN BEAUTY.—TABLES VII AND VIII.

Mountain Beauty is a pure-bred Shorthorn heifer out of Bessie Geneva 2d. As a calf Mountain Beauty was of remarkable proportions. "She is as handsome a calf as I ever saw" were the words of the President of the National Live Stock Association. Mountain Beauty dropped her first calf when she was still very young. It was thought advisable to take the calf away from her, and in despite of the high condition in which she had been kept for the fairs, to see if she would still show the tendency of her dam in the dairy line.

Mountain Beauty had not been accustomed to sugar beets before the experiment as had the preceeding cows.

BESSIE GENEVA 2d.—TABLES IX AND X.

Bessie Geneva 2d dropped her fourth calf April 9, 1902, when she was five years and eight months of age. As soon as her milk was good to use she was put on the experiment, which was in time to give her two weeks each on beets and pulp. This was the second year that she had been milked. Previous to that time her calves had been allowed to take the milk.

Sugar beets had been a part of the ration fed to Bessie Geneva 2d during the winter months of 1901–02.

FIVE COWS IN TABLES XI AND XII.

The five cows reported in these tables were scrub cows purchased to furnish milk to the College dairy. They had calved from two weeks to two months previous to the time they were brought to the College farm. None of them had been given grain or had received anything but pasture grass. When we obtained possession of them they were weighed up and put upon the experiment at once and given the same ration of grain, alfalfa, sugar beets and pulp as were the other cows. These cows are not considered in the results because they were not on the experiment long enough to give an intelligent idea of the effect of the beets and pulp.

It will be noticed in Table XII that four cows made a total loss, during the two weeks that they were fed pulp, of 255 pounds. This is probably explained by the fact that a little more than one week before this time, these cows came directly off of pasture and were put on a grain ration. It would be natural then for them to fill up for some time and apparently gain flesh during the first week on sugar beets, and then apparently lose weight rapidly during the two following weeks. For this reason the results of these cows are not used in computing the comparative cost and profits.

The results for the first five cows which were on feed long enough to make the comparison of sugar beets and pulp of some value, show that the two foods gave almost identical returns. The pulp ration gave slightly better returns when fed to Dainty Noble and Young Grannie. Bessie Geneva 2d gave more milk but not quite so much butter per week when on pulp, and also lost most flesh. The beets apparently gave better returns with Gildana and Mountain Beauty. The per cent fat in the milk varies so much that it is difficult to draw definite conclusions in regard to which ration produced the richest milk. Our averages show a little more milk from the pulp ration and a little higher fat content in milk from the beet ration.

TABLE XIII.

COST AND PROFIT—FROM FEEDING BEETS AND PULP.

AVERAGE WEEKLY.

Cow.	Food.	Cost of Food per Week.			Value Butter @ 20 cts per lb.	Value Gain @ 5 cts. per lb.	Profit from Butter.	Value Milk @ 1 ct per lb.	Profit from Milk.
		Beets.	Pulp.	Total.					
	Beets	cts. 15.7	cts.	$ 1.07	$ 1.40	$ 0.10	$ 0.43	$ 1.21	$ 0.24
Dainty Noble	Pulp.		7.47	1.00	1.41	0.58	0.99	1.23	0.81
	Beets.	15.7		1.07	0.77	0.21	—0.09	0.67	—0.49
Gildana	Pulp.		7.0	0.99	0.73	0.23	—0.03	0.64	—0.12
	Beets.	14.9		1.05	1.19	—0.33	—0.19	1.00	—0.38
Young Grannie	Pulp.		6.55	0.99	1.18	0.96	1.15	1.02	0.99
	Beets.	16.8		1.09	0.74	0.37	0.02	0.88	0.16
Mountain Beauty	Pulp.		7.46	1.00	0.72	0.00	—0.28	0.86	—0.14
	Beets.	16.8		1.09	2.82	—0.75	0.98	2.60	0.76
Bessie Geneva 2d	Pulp.		8.40	1.01	2.72	—1.00	0.71	2.79	0.78

Table XIII gives the cost of beets eaten, pulp eaten and total cost of all the food for each week, and the values of gain and products with the corresponding profit weekly for each of the five cows which were fed the longest. The cost of the beets eaten is computed from a value of $4.00 per ton on the farm, beet pulp $1.00 per ton, alfalfa $4.00 per ton, wheat chop $1.00 per hundred pounds, and corn chop $1.30 per hundred. The gain or loss in weight of the cows is valued at five cents per pound, and the butter made at 20 cents per pound to give the profit from butter. The amount of butter yield is computed from the amount of fat by increasing the total fat by 16.6 per cent. The profit from the milk production is also given and was computed in the same way, valuing the milk at one cent per pound.

Dainty Noble, on beets, gave a profit of 43 cents per week from the butter, or 24 cents per week from the milk yield. On pulp she gave a profit of 99 cents per week on butter, or 81 cents on milk.

Gildana, when fed beets, gave a loss of 9 cents from butter yield, or of 49 cents from milk yield. On pulp she gave a loss of 3 cents per week from the butter yield, or 12 cents per week from the milk yield.

Young Grannie, when fed beets, gave a loss of 19 cents per week from butter yield, or 38 cents per week from milk yield. On pulp she gave a profit of $1.15 per week from butter yield, which is the highest profit from any of the cows. Her profit is 99 cents per week from milk yield.

Mountain Beauty, when fed beets, gave a profit of 2 cents per week from butter yield, or 16 cents per week from yield of milk. When fed on pulp she gave a loss of 28 cents per week on butter yield, and 14 cents per week from yield of milk.

Bessie Geneva 2d, when fed on beets, gave a profit of 98 cents per week from butter yield, or 76 cents from her milk yield. On pulp she gave a profit of 71 cents in butter or 78 cents in milk.

The difference between the profit and losses made by all the cows while fed beets shows a total profit of 81 cents, against a total profit on pulp of $2.54. Accrediting all of the profit to the total pulp fed gives the pulp a value of $2.61 per ton, and in like manner attributing the profit made by cows on beet ration to the amount of beets which they consumed gives the beets a feeding value of $5.06 per ton.

SUMMARY.

Five cows fed 24 pounds of beet pulp for six weeks, in addition to grain and hay, made an average gain per week of 6.2 pounds. The same cows fed 12 pounds of beets per day for five weeks made an average gain per week of one-fifth pound.

Five cows on the pulp ration gave an average weekly milk yield of 131.1 pounds, and on the beet ration they gave an average weekly milk yield of 127.4 pounds.

Five cows on the pulp ration gave an average weekly butter yield of 6.76 pounds, and on the beet ration an average weekly butter yield of 6.90 pounds. The milk contained a little more butter fat when the cows were fed sugar beets.

A little more than three times as much profit resulted from feeding 24 pounds of pulp per day than was realized from 12 pounds of beets per day, at one dollar and four dollars per ton respectively.

The total profits indicated a feeding value of the pulp for butter production of $2.61 per ton, and of the beets of $5.06 per ton when fed in small amounts, and when butter is worth 20 cents per pound.

Bulletin 74. September, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

SWINE FEEDING IN COLORADO.

BEET PULP AND SUGAR BEETS FOR FATTENING HOGS.

HOME GROWN GRAINS VS. CORN FOR FATTENING HOGS.

OTHER TRIALS WITH CORN, BARLEY, ALFALFA AND BEETS.

—BY—

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PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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SWINE FEEDING IN COLORADO.

(*a*) Beet Pulp and Sugar Beets for Fattening Hogs.
(*b*) Home-Grown Grains *vs.* Corn for Fattening Hogs.
(*c*) Other Trials with Corn, Barley, Alfalfa and Beets.

BY B. C. BUFFUM AND C. J. GRIFFITH.*

The general conclusions which may be drawn from the experimental investigations reported in this bulletin will be found in condensed form on the last pages, and we suggest that the busy man who is willing to accept our testimony may profitably omit the reading of all intermediate material, except the pictures.

The last enumeration of hogs in Colorado (1901) credited the state with 101,198 head. There are, according to the census, 2,273,968 acres of land irrigated, and the farms and ranches number 24,700.

The scarcity of swine in the state is due largely to the system of farming in vogue which allows a great majority of the stock raised on ranches to run at large on the range in the mountains or on the plains a large part of the year, keeping them on the ranch only during the cold months. This system reduces the expense of raising stock to a minimum. Every animal that can be spared from the ranch is thus grazed on lands that cannot be farmed and consequently have a small value. Outside of the dairies there are not a great many cows milked. The total number of cows in the state is about 20,157, according to the 1900 census report. The milk cows and the work horses constitute the ranch live stock during the greater part of the year. Then, too, there are not a great number of cattle fattened in the state and so there is not the demand for hogs to follow the cattle in the feed lots.

A third reason is the lack of information among our farmers of the feeding value of our home-grown grains for

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fattening hogs. Corn is not grown to any extent in Colorado, except for fodder, and it is entirely reasonable that it will never be grown extensively because of existing climatic conditions. There is an occasional farmer that raises some corn each year, but they are mostly in favored localities where the nights are warmer than our average condition. It will follow then that our steers will continue to be shipped to the corn belt states to be fattened, and the demand for hogs to follow cattle in the feed lots will be small.

Will it then pay to raise and fatten hogs for market in Colorado? If it will pay, will it pay better than some occupation to which our farmers have access at present? Let us look first at the products of the farming or ranching communities. In the Cache la Poudre, Big Thompson, St. Vrain and South Platte Valleys, which constitute the irrigated section of northeastern Colorado, alfalfa is the principal product grown. Wheat comes next, with oats and potatoes following in succession. The raising of sugar beets is assuming remarkable proportions and may eclipse some of the former products in acreage and importance. The cultivating and harvesting of these crops occupy the summer months. Lamb feeding is the principal winter occupation and assumes larger and larger proportions each year, as it affords profitable disposition for the immense quantities of alfalfa raised, and earns a large percent for the skill of the feeder and the capital invested. Cattle raising is the chief agricultural industry of the whole state, and together with the raising of horses and sheep, doubtless must ever be foremost, because of the many million acres of semi-arid plains that grow nutritious native grasses, and which do not produce a paying crop under cultivation. Then there is the vast mountain region that supports on its precipitious slopes sleek cattle, horses and sheep. Together these two ranges maintain, according to the last statistics, 1,333,202 cattle; 236,546 horses, and 2,044,814 sheep. As stated before, this stock is kept on the ranches only about two months each year, and it is only those that have the best of care that remain that long where there is shelter and hay. So this class of stock would not interfere with hog raising in the least, and hog raising and lamb feeding would be mutually beneficial. The time spent in caring for a bunch of hogs would not interfere with the farming operations any more than it does in other places.

The one consideration then should be whether capital invested in hogs would yield as good returns as invested elsewhere on the farm. This may be judged, in part

at least, by the results of these experiments. We must decide whether we have forage crops and grains to properly raise and fatten hogs, or whether it would be advisable to ship in such foods.

Unlike lambs, hogs will not consume a large amount of rough forage and make as profitable a gain therefrom, but they must be fed a more concentrated or less bulky ration. The stomach of the sheep holds only 30 to 34 quarts, while the stomach of the hog holds from 7 to 9 quarts. Under our conditions profitable lamb feeding and profitable hog feeding must be different questions carried out along different lines. Lambs naturally fit into our system of farming to use up the surplus alfalfa hay. Unless we can feed home grown products to hogs with profit they will not fit into our conditions in the same way, though our pasture conditions for them are ideal.

ALFALFA FOR PASTURE.

It is essential in raising hogs to have some pasture grass for them. Especially is this true of the brood sows and the young pigs which need not only the green feed but the exercise and sunshine out of doors. Alfalfa fulfills this requirement admirably, as it makes a forage which is perfectly safe for hogs to pasture, is nutritious, palatable, grows early in the spring and late in the fall. Alfalfa produces more green forage per acre than any other forage used for hog pasture in the central west. Colorado is credited with 799,611 acres of this crop. It is essential to every ranch where mixed farming is carried on. Alfalfa is grown to such an extent in the state that any farmer or stockman could spare a few acres for hog pasture. The value of an acre of alfalfa throughout the season for laying on pork has not been reported from any station, but long experience has taught practical hog raisers that a little corn or a small amount of other grain, together with good alfalfa pasture, will give excellent returns. Alfalfa alone seems to supply little more than a maintenance ration, but as such is very valuable.

BEET PULP.

With the growth of the sugar beet industry and the building of factories for the manufacture of beet sugar, within the state, an important by-product, beet pulp, has been added to the list of foods available to stock feeders. Pulp is made by cutting sugar beets up into shreds about one-half the size of an ordinary lead pencil in order to extract the sweet juices from them by allowing the mass of shredded

beet to soak in a constantly moving bath of hot water until the sugar is dissolved out. Thus the pulp comes in contact with no chemicals whatever to impair its healthfulness as a food product. Any unhealthful property that the pulp might have must therefore be laid to outside contamination or other causes, and not to any process in the manufacture of sugar from the beets. After coming out of the hot water bath, the pulp is run into an immense vat or storage silo for future disposition.

The purchase price of pulp in this state is 35 to 50 cents per ton at the factory and a lower price than this is often made to farmers who furnish beets.

Beets produce approximately fifty percent of their weight of pulp, and in some places an amount of pulp is given back corresponding to the amount of beets furnished. Extravagant prices have been paid for pulp in some instances. A note published in one of the eastern farm papers quoted a price per ton obtained for pulp one dollar in excess of the price paid originally for the beets. Where the pulp has to be shipped from the factory for a short distance an additional sum, say fifty cents per ton, would have to be added to the price to pay freight. Then there is the hauling of it from the car, which makes another item of expense of say 25 cents per ton if the distance is two miles or less. This makes the total expense 75 cents per ton plus the price of the pulp at the factory. This would make the total cost, within a reasonable distance of the factory, $1.25 per ton for wet pulp. The loss of water will cause continual shrinkage. The amount of shrinkage cannot be estimated, but will depend largely upon whether the pulp has been pressed at the factory, or whether it is obtained from the discharge pipe or taken from the silo where it has drained for a greater or less length of time.

The palatability of pulp, when properly handled, is unquestioned. Our experience at this Station is that horses, cattle and sheep, and especially such of these as are used to roots, relish pulp and will eat it greedily. Our pure bred sheep that are kept on the College farm broke through the fence repeatedly to get at a pile of pulp. The horses also were especially fond of it, and while the cattle did not appear so greedy they ate it heartily. A little difficulty was encountered in getting some Mexican lambs, with which we were experimenting, to eat the pulp, but in a few weeks time they were consuming a considerable quantity of it. The hogs used in this experiment acted much the same way, not caring for the pulp and almost absolutely refusing to

eat it for some time. The grain fed was mixed with the pulp and in a few days they were eating the mixed pulp and grain greedily.

The low per cent of nutrients in pulp does not give it a very good recommendation as a food. The composition of Colorado pulp as determined by Dr. Headden, compared with alfalfa, runs thus:

	Dry Matter in 100 lbs.	Digestible Nutrients in 100 lbs.		
		Protein.	Carbo-hydrates.	Ether Extract.
Beet Pulp	10.0	0.38	7.36	.02
Alfalfa	91.6	11.00	39.60	1.20

Dr. Headden states that his analyses were made of grated pulp which probably contained a minimum amount of nutrients. The California Experiment Station gives a somewhat higher composition than the foregoing. Analysis quoted from Herbert Myrick's book on "The American Sugar Industry," p. 108.

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Ext.
Beet Pulp	10.0	1.3	6.7	0.4

Taking our own analysis showing the smallest amount of foods in one ton of beet pulp there are 200 pounds of dry matter, of which 7.6 pounds are digestible protein; 147.2 pounds digestible carbohydrates, and 4 pounds digestible ether extract. In alfalfa there are 1832 pounds of dry matter in one ton, of which 220 pounds of protein are digestible and 792 pounds of carbohydrates are digestible, and there are 24 pounds of digestible ether extract. As alfalfa is worth about four times as much as pulp costs laid down on the farm, we readily see that in the matter of composition the pulp makes a poor showing. This is illustrated in the following table of comparative values:

	Dry Matter in 2000 lbs.	Digestible Nutrients in 2000 lbs.		
		Protein.	Carbo-hydrates.	Ether Extract.
One ton Pulp worth $1.00	200	7.6	147.2	0.4
500 lbs. Alfalfa worth $1.00	458	55.0	198.0	6.0

However the feeding value of pulp may not be definitely determined by the percentage composition because the pulp is not used as a basis food but as a condiment or succulent sauce to increase the appetite and aid digestion, and in that respect it may have a value which would make it profitable to feed under certain conditions. If two or even four pounds of pulp per head each day would help the digestion of the other foods fed, or if in a preliminary feeding

period pulp could be used in a ration to put animals in a condition to fatten readily. then it might have a value even in excess of the $1.00 or $1.25 per ton. It has been clearly demonstrated that for fattening hogs the corn cob has a value when ground up with corn, because it lightens the meal in the stomach and thus makes it more digestible. It is not beyond the range of possibility that pulp may serve this same purpose in a region where ear corn is uncommon, and at the same time furnish some nutrients in the ration.

KEEPING QUALITY OF PULP.

There are various methods for the preservation of pulp. In some parts of Utah where rock salt is plentiful, large pits are dug in the ground and quantities of salt are thrown into the pulp when it is being put into this pit, which, it is claimed, makes a splendid silo. When the pulp is exposed to the weather the top layer dries out and the pulp further down forms a thick pasty layer five or six inches deep. This layer excludes the air and keeps the pulp fresh and sweet. During this experiment we had pulp in piles on the ground from the first of January until late in June. It was preserved in an unfermented, or only slightly fermented, condition until the early part of June, when warm weather came on. When it is desirable to keep pulp no longer in the season than this, it is just as well to pile it on the ground. If it is to be kept through the summer, most any form of silo is effiicent, and in deep piles it has been known to keep two or three years.

SUGAR BEETS.

A conservative estimate of the sugar beets grown in the state this year (1902) for the factories would be 35,000 acres. This will yield approximately 350,000 tons of sugar beets which, if made into sugar, will give more than 150,000 tons of pulp. Besides this there is a large acreage being grown for feed. Numerous requests have been received by this department asking for information of the feeding value of sugar beets for all kinds of live stock. Reports have come in of feeders paying more for sugar beets than is paid by the factories. Large quantities have been fed the last two years with evidently good results, and in many places feeders have made special arrangements for sugar beets for their stock the coming season.

There is no question about the feeding value of these beets for stock-cattle, sheep and hogs, to maintain health,

thrift and breeding qualities; but their value when used as the basis of a fattening ration is not so well determined. As this is the way they are being used in this state, several experiments with beets were planned to determine whether or not they can be made a part of a fattening ration with profit. Many farmers have reported feeding them alone to hogs with good results, but the chemical composition of sugar beets is prima facia evidence that hogs cannot make good and profitable gains when fed on beets alone, because there is not sustenance enough in the amount of them a hog can eat and digest, to do much more than maintain the animal at a constant weight. According to feeding standards, a hog weighing 200 pounds to make the best gain, needs digestible nutrients as shown in the following table:

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Ext.
Standard for 200 lb. hog	6.4 lbs.	0.8 lbs.	4.8 lbs.	0.1 lbs.

CHEMICAL COMPOSITION OF SUGAR BEETS.—POUNDS IN 100.

Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Extract.
20.0	1.135	16.007	0.051.

In 25 pounds of sugar beets there would be digestible nutrients as follows:

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Extract.
Sugar Beets 25 lbs.	5.0	0.284	4.002	0.013

Twelve and a half pounds was all we could get a hundred-pound hog to eat in one day during the experiment. By comparison it will be seen how far short of the standard 25 pounds of beets would be for a two hundred-pound hog, were it possible to get him to eat that amount. However, if beets could be made to take the place of some grain in the fattening ration supplying them might be of advantage.

HOME GROWN GRAIN VS. CORN.

By home grown grains is meant wheat, barley, oats, and such other small grains as are grown in Colorado. It would be hard to give an intelligent estimate of the amount of corn that is annually shipped into the state for feeding purposes. Feeders have frequently resorted to home grown grains during periods of high prices of corn. It is a common custom to trade wheat and barley off for corn. Even this last winter when wheat was $1.00 per hundred pounds, and at one time as low as 90 cents per hundred, feeders

hauled in wheat and took home corn at $1.30 per hundred. Barley was selling at about the same figure as wheat. The acreage of wheat as given in the government reports for 1900, was estimated at 318,899 acres; barley, 12,672 acres, oats, 99,768 acres; rye, 2,350 acres. The combined yield of these four grains for that year approximated 11,000,000 bushels.

It is a well known fact that under irrigation the small grains produce plumper, larger kernels giving greater weight per bushel, and that the chemical composition differs widely from that of grains grown under rainfall conditions. Repeated feeding experiments in other states have shown wheat to be fully equal to corn for fattening hogs, and barley to be worth about 8 percent less than wheat or corn Prof. W. W. Cooke, formerly of this Station, made an extensive and exhaustive experiment comparing barley and corn, both whole and ground, for fattening hogs, with the following results:

	No. Tests.	Av. Weight at Beginning.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
		lbs.	lbs.	Grain lbs.	Skim Milk qts.	Grain lbs.	Skim Milk qts.
Whole Corn..	6	71	0.39	2.0	0.7	7.0	1.1
Ground Corn	5	60	0.46	2.4	1.0	5.4	1.1
Whole Bald Barley............	8	88	0.58	2.3	1.2	5.0	1.3
Ground Bald Barley	5	67	0.74	2.4	0.8	3.6	0.8
Whole Common Barley.	4	68	0.49	2.3	0.5	5.4	0.7
Ground Common Barley......	4	47	0.70	2.4	1.1	4.3	1.1
Ground Corn and Barley	4	50	0.77	2.1	1.0	4.1	0.8

This experiment shows the superiority of irrigation grown barley over rainfall corn and thus over rainfall grown barley.

The average price of corn in Colorado for the past ten years has been 80.5 cents per hundred pounds; wheat 99.5 cents; barley 55.1 cents. An average for wheat and barley of 77.3 cents. or 3.2 cents per hundred less than corn. If

then, our home grown grains are worth less money right on our farms than corn in town, and in turn either of them singly will produce more pork per pound than will corn, and when fed mixed are far superior to corn, have we not the solution of the problem of supplying concentrates which will profitably fatten hogs? (In this connection special attention is called to Summary of Lot IV. in the 1902 Experiment, page 22). Together with the alfalfa for forage and the sugar beets and their by-products for roughage, Colorado should become a factor in the production of pork.

OBJECT OF EXPERIMENT IN 1902.

To test the value of pulp and sugar beets when fed with grain; the value of sugar beets alone; and these three compared with corn, wheat and barley, was the purpose of this experiment. It is really a comparison of home grown foods vs. corn and is a continuance of experiments previously carried out with both swine and sheep. It is also important at this time to be able to give something definite about the value of sugar beets and pulp for all classes of stock. There will be in excess of 150,000 tons of beet pulp available for feeding this fall and winter. To be able to utilize this for wintering or fattening stock would add vastly to the live stock industry. So large a subject is this feeding of pulp that this bulletin does not attempt to treat more than partially the utility of pulp for fattening swine.

PLAN OF EXPERIMENT.

Twenty shoats were divided into five lots of four each. Care was taken in selecting the individuals for each lot, that each pen should be as representative as possible for the entire number. Each lot had the same sized pen in the piggery and each had access to the small yards adjoining.

Pigs in Pen I. were fed sugar beets alone.
Pigs in Pen II. were fed beet pulp and ground wheat and barley.
Pigs in Pen III. had shelled corn.
Pigs in Pen IV. were given ground wheat and barley.
Pigs in Pen V. were given sugar beets, ground wheat and barley.

For the pigs in Pen I. the sugar beets were chopped into small pieces and the pigs were given all that they would eat of them. Fresh, clean water was supplied twice daily at feeding time. Besides this, the shoats had access to nothing but the straw used for bedding, except an occasional small quantity of ashes or coal which was supplied to all pens alike. These pigs were fed to see just what hogs

would do on sugar beets alone, because some of our farmers had been doing this and we wished accurate data for a check.

The hogs in Pen II. were fed a large quantity of pulp, especially during the first part of the experiment. It was necessary to mix the grain with the pulp to get the pigs to eat the pulp.

The hogs in Pen III. were fed shelled corn alone, having access to nothing else but the straw used for bedding, besides plenty of water and some coal and ashes. It might have been better to have fed the corn ground, especially as the pigs were young and growing rapidly, and again because ground wheat and barley were fed.

The hogs in Pen IV. were fed equal parts of ground wheat and barley, for comparison with Pen III.

The pigs in Pen V. were fed in all respects like those in Pen II., except that sugar beets were substituted for the pulp. In the results from these two pens, we have a comparison of the value of pulp and the value of sugar beets when fed with grain. Pens II. and V. also may be compared with Pen IV., thus giving the advantage, if any, of feeding pulp or sugar beets with grain for fattening hogs.

The feed given was carefully weighed and any remaining uneaten until the time of the next feeding was weighed back. The hogs were ear-tagged and weighed separately once a week, thus giving the individual differences of those in the same pen. Additional notes were kept as to the general condition of the individual hogs in each lot so that, at the end of the experiment, it would be known whether or not the best results possible had been attained under the conditions. We have been assisted in these experiments by Mr. Fred Bishopp and Mr. W. B. Smith, senior agricultural students, who carried out the feeding as planned and aided in keeping the records.

KIND OF HOGS FED.

The hogs used in this experiment were obtained from the slaughter house yards of wholesale butchers within the city. From appearances the hogs were grade Poland Chinas and Berkshires. From the information that could be gleaned from those in charge, the pigs had been bought from different farmers in the vicinity and had been at the yards only a short time before we obtained possession of them. They were only common scrub shoats and did not show that any special care had been taken of them. They were probably late spring pigs and approximately eight

months of age. Their average weight was close to 100 pounds at the time they were put on the experiment. It was necessary to pay 6 cents a pound which was too high a price for pigs of their weight and breeding.

PULP FED.

The pulp fed was obtained from the Loveland factory of the Great Western Beet Sugar company, whose manager, Mr. A. V. Officer, courteously supplied us a carload for experimental use. Laid down at the College farm it cost us approximately $1.00 per ton. This pulp was piled out on the ground about January 1, 1902, and was used as it was needed for feeding. The ground on which it was piled had good drainage and the moisture from the pulp drained away as it seeped out, Thus, in a few days time, the pulp was in nice condition, comparatively dry, and was preserved in an unfermented condition much better than some other piles of pulp which we had placed where the moisture did not drain away.

BEETS FED.

The sugar beets used in this experiment were grown upon the College farm, put in a root cellar after digging, and taken out as there was need of them. During the latter days of the experiment, the supply of sugar beets was exhausted and a stock beet was substituted in their stead. They were fed stock beets only about two weeks, the time being so short the final result was probably not changed by the substitution. The beets fed were figured at $4 per ton. This would be equal to from $4.50 to $5 per ton for beets delivered at the factory; first because of the expense of hauling or shipping them to the factory, and second the work and expense of trimming the beets, which would amount to at least 50c per ton.

GRAIN FED.

The wheat and barley fed were also grown upon the College farm. The wheat was of the common Defiance variety and was grown in a field producing 34 bushels per acre. The barley fed was of the common hulled variety and was grown in a field which produced 25 bushels per acre. Together they were rated at $1 per hundred pounds, which we think is not too low an estimate to put upon these grains, as there was considerable time during the late fall when either wheat or barley could have been purchased below that mark.

EXPERIMENT OF 1902.

SUGAR BEET PRODUCTS, AND HOME GROWN GRAINS.

On February 19th, twenty hogs were weighed and put upon the experiment. Previous to this time they had been kept together on the same ration for one week. In their drinking water they had been given a weak solution of sulphuric acid to free them from intestinal worms. They had also been sprayed for lice with 3 percent solution of Zenoleum. The pigs at this time were in a healthy, growing condition, and as will be seen in the summary, they averaged approximately 100 pounds each.

Those in Pen I. did not take very readidly to the sugar beets and it was evident that they had never been used to a ration with roots in it, but they very soon began to eat the beets heartily.

Those in Pen II. would not touch the pulp fed them for several days. From February 19th to 22d inclusive, the four pigs in this lot were given only 40 pounds of pulp, and eight pounds of this were weighed back as orts which they did not eat.

The pigs in Pens III. and IV. took hold of the food given them readily, as also did those in Pen V., fed with the wheat and barley in addition to the beets. They ate the sugar beets, but apparently did not relish them at first.

Table I. which follows, gives the amount of food fed in periods of one week each for each pen, also the total amount of food eaten by the pigs in each pen. On May 30th, the hogs in Pens I., II., and two from Pen III., were slaughtered. Those remaining were slaughtered on June 6th.

Table I. is of interest as it shows the consumption of food week by week. The pigs were given approximately all they would eat. The pigs in Pen I. ate an increasing amount of sugar beets up to May 3d, within four weeks of the end of the experiment. They seemingly had eaten so many beets during the week ending May 3d that they became tired of them and would not again consume as large amounts.

The pulp fed to the pigs in Pen II. was increased until March 22d, and then decreased because the grain was increased for finishing the pigs and it was thought advisable to cut down the large amount of succulent food.

TABLE I.

FOOD EATEN.

Date.	Pen I	Pen II		Pen III	Pen IV	Pen V	
	Sugar Beets.	Wheat and Barley.	Pulp.	Corn.	Wheat and Barley.	Wheat and Barley.	Sugar Beets.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
February 19–22	117	35	40	48	45	31	28
February 22-March 1	230	72	123	89	102	74	57
March 1–8	239	70	232	70	123	75	70
March 8–15	280	70	285	79	131	98	80
March 15–22	287	79	294	98	140	98	94
March 22–29	302	90	291	112	149	98	116
March 29-April 5	308	84	251	112	154	98	126
April 5–12	308	116	168	112	154	98	126
April 12–19	324	126	168	112	154	118	126
April 19–26	324	126	168	112	154	126	134
April 26-May 3	318	126	168	112	154	126	130
May 3–10	324	126	172	112	154	126	140
May 10–17	264	126	172	112	154	130	100
May 17–24	182	126	172	112	154	138	80
May 24–30	270	90	120	96	154	126	128
To June 4	......	....	......	44	110	104	20
Totals	4107	1372	2824	1534	2186	1664	1565

The pigs in Pen III. on corn, and those in Pen IV. on wheat and barley, practically consumed increasing amounts of food up to the end of the experiment and the respective lots practically consumed the same amounts of grain each week for the last nine full weeks. The last four weeks the amount of sugar beets given to those in Pen V. was reduced, but the grain was increased as they would consume it.

Table II. page 17 gives the individual weights each week for all the pigs. The last column gives the total gain of each pig during the experiment and the first column the ear-tag number. Food given each lot is given in Table I. The last weight of each pig, taken May 30th or June 6th, was made after they had been off feed for 24 hours before slaughter, and represents the gain during the last week, less the shrinkage. Pig No. 80, in Pen II, was found to be in pig soon after the feeding began and was left with the lot to see what the final effect would be. She dropped a litter of three pigs March 29th and killed all of them. She was left on feed and made a larger total gain than any other pig in that pen.

Table III. gives the total weekly gains made by the four pigs in each pen and the last column gives the total gain of each lot for the whole period, less the 24 hours shrinkage before slaughter. The minus sign before a number indicates a loss of weight. There is much variation in the gains made week by week, the differences being especially noticeable in Pen I., fed on sugar beets, and in Pen II., given pulp and grain. The gains did not vary so much with the grain rations.

TABLE III.

EXPERIMENT NO. I.—SWINE FEEDING. POUNDS GAIN PER WEEK.

	February 22	March 1	March 8	March 15	March 22	March 29	April 5	April 12	April 19	April 26	May 3	May 10	May 17	May 24	May 30	June 4	Total Gain
Pen I	25	-5	-6	6	18	-10	6	4	6	4	-4	19	-11	25	-10		67
Pen II	22	8	32	6	62	-1	29	10	39	33	41	40	0	20	11		352
Pen III	30	7	-12	30	32	5	35	12	26	21	31	16	16	7	22	7	285
Pen IV	29	24	12	51	49	11	55	29	33	29	49	47	37	14	33	-21	481
Pen V	16	19	16	26	25	25	34	24	32	32	36	38	39	22	13	-5	392

PLATE I.

Representative Carcasses from Lots III, IV and V.
No. 84, Fed Corn.
No. 75, Fed Wheat, Barley and Sugar Beets.
No. 73, Fed Wheat and Barley.

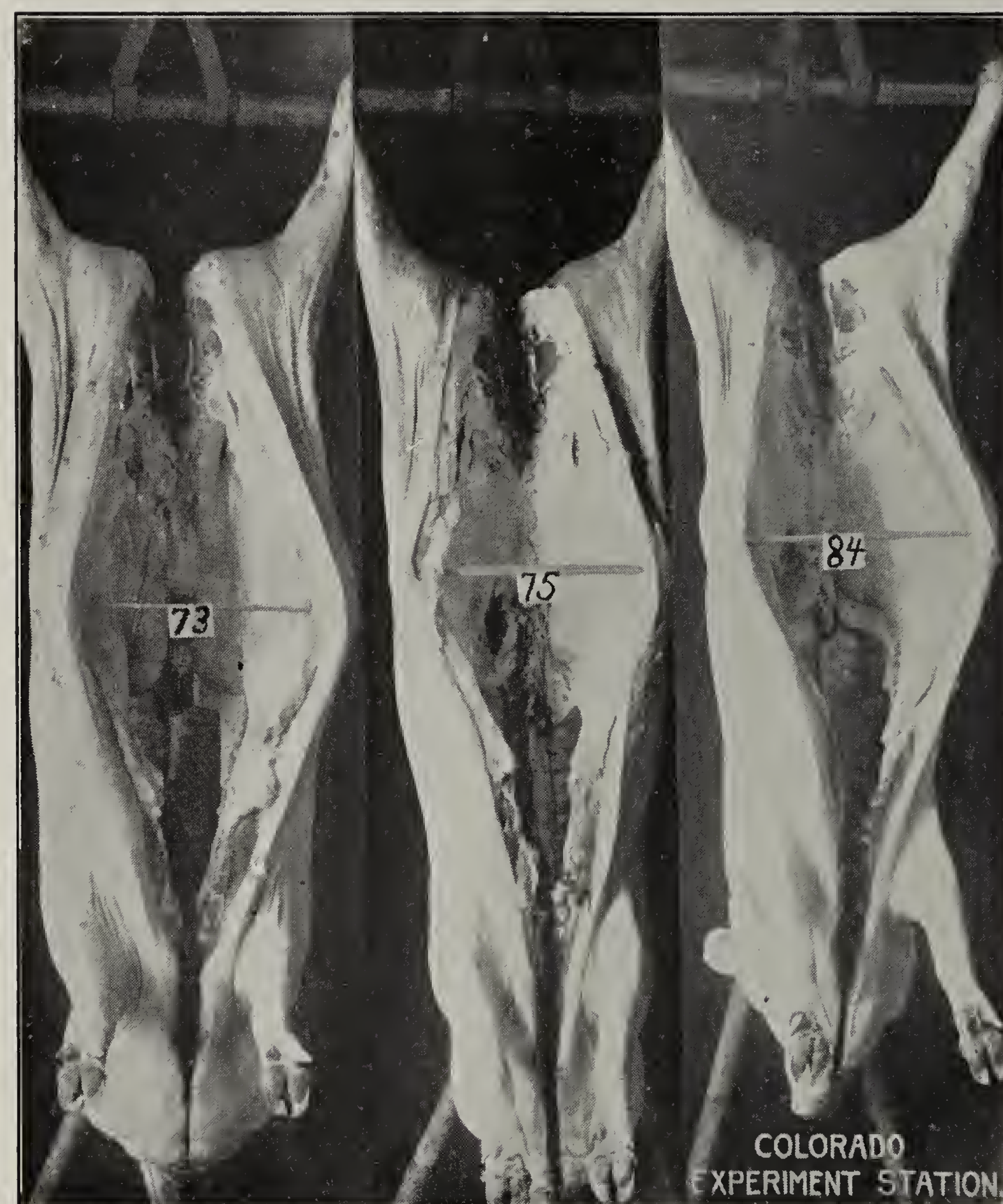

PLATE II.

Representative Carcasses from Lots III, IV and V.
No. 84, Fed Corn.
No. 75, Fed Wheat, Barley and Sugar Beets.
No. 73, Fed Wheat and Barley.

TABLE II.

	No. Tag	February 19	February 22	March 1	March 8	March 15	March 22	March 29	April 5	April 12	April 19	April 26	May 3	May 10	May 17	May 24	May 30	June 6	Total
		lb	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I	574	110	117	124	112	114	115	115	116	118	119	119	124	122	121	131	128		18
	582	90	100	91	94	94	99	97	96	96	96	99	102	100	97	104	102		12
	181	106	110	108	110	112	118	115	118	118	121	122	124	127	125	130	127		21
	562	95	99	98	99	101	107	102	105	107	109	109	95	115	110	113	111		16
Pen II	80	107	118	121	128	140	158		148	154	163	172	183	191	196	204	207		100
	585	90	96	100	106	108	118	115	129	125	133	139	149	157	162	162	165		75
	577	95	96	95	108	100	118	121	134	140	153	162	174	181	183	190	191		96
	81	95	99	101	106	106	122	121	123	135	144	153	161	179	167	172	176		81
Pen III	77	110	117	117	114	124	131	131	141	145	149	156	159	169	173	174	178		68
	78	90	96	98	96	103	112	116	122	126	133	139	149	147	150	154	159	162	72
	79	90	91	94	91	97	105	108	117	120	128	134	142	147	150	154	159		69
	84	90	106	108	104	111	119	117	127	128	135	137	147	150	156	154	162	166	76
Pen IV.	73	115	120	123	130	143	155	158	170	180	182	193	202	219	230	239	249	241	126
	70	100	109	117	114	127	140	146	157	165	176	180	193	201	210	213	221	218	118
	74	98	104	114	122	132	143	149	166	173	181	194	209	223	230	236	244	239	141
	83	65	74	77	77	92	105	101	116	120	132	133	145	153	163	159	166	161	96
Pen V.	75	108	118	124	126	137	145	149	158	164	176	185	193	206	215	219	225	228	110
	87	95	93	97	99	105	115	116	125	131	139	148	155	161	173	179	183	184	89
	72	95	97	105	109	109	109	123	131	135	144	150	156	159	175	179	175	179	84
	85	105	111	112	120	129	136	142	150	158	161	169	184	200	202	210	217	204	99

FOOD EATEN DAILY.

The average amounts of food eaten per day throughout the experiment for each hog in each pen were as follows:

TABLE IV.

FOOD CONSUMED DURING EXPERIMENT.

	No. of Hogs.	Days Fed.	Average Food per Hog.				Average Weight and Gain per Hog.		
			Corn	Wheat and Barley.	Sugar Beets	Pulp.	Beginning.	End.	Gain.
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I...............	4	99			1026.75		100.25	117.00	16.75
Pen II............	4	99		343.00		706.00	96.75	184.75	88.00
Pen III............	4	101	383.50				95.00	166.25	71.25
Pen IV	4	104		546.50			94.50	214.75	120.25
Pen V	4	104		416.00	391.25		100.75	198.75	98.00

DISCUSSION OF RESULTS.

In Table IV. is given the amount of food consumed, stated in averages for each animal in the different lots, and the average weight and gain of the four pigs in each pen at the beginning and end of the experiment.

TABLE V.

FOOD EATEN DAILY.

	Average Food Per Day.				Gain per Head per Day.
	Sugar Beets.	Wheat and Barley.	Pulp.	Corn.	
	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I..............................	10.37				0.17
Pen II..............................		3.46	7.10		0.89
Pen III...........				3.80	0.70
Pen IV..............		5.25			1.16
Pen V.........................	3.76	4.00			0.94

Table V. gives the average food per head eaten daily. The pigs in Pen I. ate 1,026.75 pounds of sugar beets, or 10.37 pounds per day, on which they made average total gains of

16.75 pounds. The pigs in pen V. ate 391.25 pounds of sugar beets, or 3.76 pounds per day, and 416 pounds of grain, or 4 pounds per day, or a total of 807.25 pounds of food, making an average gain of 88 pounds.

The food given to Pen I. did little more than maintain the original weight of the animals, while in Pen V. one-third the amount of beets in addition to four pounds of grain per day produced substantial gains. The pigs in Pen II. ate 706 pounds of beet pulp, or 7 pounds per day, and 343 pounds of grain, or 3.64 pounds per day. The total amount of feed consumed by each pig was 1049 pounds, a little more in weight than was eaten by Pen I. The total gain was 88 pounds, or only ten pounds less than that made in Pen V. on 63 pounds more grain and a little more than one-half the weight of beets, but the ration in Pen V. is appreciably greater in cost than that given in Pen II.

Pens III. and IV. give us a comparison of the amounts of corn and wheat and barley consumed, with their respective gains. The pigs in Pen III. ate 383.5 pounds of corn, or 3.8 pounds per day, making average gains of 71.25 pounds. In Pen IV. each pig ate 546.5 pounds of grain (equal parts wheat and barley) or 5.25 pounds per day, making average gains of 120.25 pounds.

Wheat and barley is shown to have had a decided advantage over corn in this experiment. When the chemical composition of corn and wheat and barley is taken into account, these results are not surprising. In corn there is not sufficient digestible protein,—or the muscle, blood and bone-building element—in proportion to the carbohydrates—or fat and heat-producing element—for the most economic gain. This porportion of protein to carbohydrates is called "nutritive ratio." For fattening hogs this nutritive ratio should be about 1 to 7 (one part protein to seven carbohydrates), to obtain the best results. In corn this ratio is 1 to 9.7, while in equal parts wheat and barley it is 1 to 7.5. It is usual to feed some substance richer in nitrogen with corn in order to make the ration nearer the correct standard. The fact that wheat and barley mixed in equal parts furnishes a ratio so nearly correct may account for their greater palatability, making the pigs consume so much larger quantities of these grains than they would eat of corn alone, and as would be expected, they made greater gains.

COST AND PROFIT.

The true measure of the efficiency of a food ration for fattening stock is the value of the resulting product after

the cost has been deducted. In Table VI. will be found a comparison of the cost of the food consumed by each animal and the first cost of the feeders and the profit at selling prices of six cents and seven cents per pound. Six cents per pound for the feeders was too high a price in the beginning. Seven cents per pound at the close of the experiment was not too high a price, so our statement of profit based on this buying and selling price is a conservative one. Feeding in small lots and experimentally as we did, makes it impossible to state fairly the cost of the labor used, but this is not necessary in order to make a true comparison of the different foods under investigation. The farmer who has had any experience in feeding swine can estimate this item for himself. The feeding is usually done at a season when the farmer's time, or that of his men, is not considered so valuable, and the pig feeding comes in after hours any way as chores. This is not an attempt to slight or ignore the question of labor at all, for it is a real one, but every farmer must estimate this item of expense for himself. There is no attempt made in this bulletin to show the cost of raising pigs up to the time they weigh 100 pounds. They were bought at 6 cents per pound and the results are figured from that basis. A large profit would be realized on pigs grown to that weight which could be sold at six cents per pound.

The total cost of the food eaten by pigs in Pen I. averaged $2.05. The total profit on each head at 7 cents was 13 cents, and at 6 cents there was a loss of $1.04 on each. Although the cost of the food was small, the profits were unsatisfactory because the gain in weight was so small.

Pen V., with a total cost of food of $4.94 per hog, made a total profit of $.95 at 6 cents per pound, and at 7 cents per pound a total profit of $2.93. The pigs in Pen II. ate $3.78 worth of food per hog and made a total profit of $1.50 when figured at 6 cents per pound, and $3.35 at 7 cents per pound.

Pen II did not make as large a total gain by ten pounds per hog as Pen V. (see Table VI), but they did not consume as much grain by 73 pounds for each animal. While the pigs in Pen II. ate more than twice the amount of pulp, the cost of the pulp given each hog was not one-half as much as the cost of the beets given to Pen V. In the total profit then, the extra gain in live weight made by Pen V. was more than balanced by the cheapness of the ration fed to Pen II.

Pen III., with $4.98 charged against each animal for

corn, made a total profit of $.95 per hog, figured at 7 cents per pound, and at 6 cents they made a loss of $.71. The value of the food consumed by Pen IV. was $5.46 per hog. The total profit at 6 cents was $1.75 each, and $3.90 at 7 cents.

TABLE VI.

COST OF FOOD AND TOTAL PROFIT.

	Average Cost of Food Eaten.				Average Total Cost Food Eaten.	First Cost @ 6 cts per lb.	Average Total Profit.	
	Corn @ $1.30.	Wheat and Barley @ $1.00.	Sugar Beets @ 20 cts cwt.	Pulp @ 5 cts cwt.			@ 6 cts per lb.	@ 7 cts per lb.
Pen I..........			$2.05		$2.05	$6.01	—$1.04	$0.13
Pen II.........		$3.43		$0.35	3.78	5.80	1.50	3.35
Pen III........	$4.98				4.98	5.70	—0.71	0.95
Pen IV........		5.46			5.46	5.67	1.75	3.90
Pen V.........		4.16	0.78		4.94	6.04	0.96	2.93

POUNDS OF FOOD AND COST FOR ONE POUND OF GAIN.

Table VII. gives the cost of the average amount of food eaten by each pig, at the current prices for the feeds used, and the actual cost of each pound of gain made during the fattening period. In next to the last column of the table is given the final cost for each pound of dressed pork which shows the amount per pound which would have to be received for the dressed meat in order to merely balance the cost of the food consumed.

TABLE VII.

FOOD FOR ONE POUND GAIN.

	Average Food for One Pound Gain.				Average Cost per pound of Gain.	Average Cost per Pound of Dressed Pork.	Percent of Dressed Meat.
	Corn	Wheat and Barley.	Sugar Beets.	Pulp.			
	lbs.	lbs.	lbs.	lbs.	cts.	cts.	%
Pen I.....			61.3		12.3	8.9	77
Pen II..................		3.9		8.	4.3	6.5	80
Pen III	5.4				7.	8.	80
Pen IV..................		4.5			4.5	6.1	84
Pen V...................		4.2	4.		5.	6.8	84

While sugar beets cost less per pound than any other food, except pulp, it took 61.3 pounds of beets for each pound of gain made at a cost of over twelve cents. There was a comparatively large amount of waste in the beet fed lot, as they dressed only 77 percent of the live weight.

The pigs in Pen II. ate 3.9 pounds of grain and 8 pounds of beet pulp for each pound of gain. This made the cost of each pound of gain 4.3 cents and the cost of each pound of dressed pork 6.5 cents. They dressed 80 percent of the live weight which is a little better than the beet fed lot and is the same as the corn fed lot.

The pigs in Pen V. which were given the same kind of grain as the pulp fed lot in Pen II. and sugar beets instead of pulp, ate just a little more grain, 4.2 pounds, and one-half the amount of beets, or 4 pounds, compared with 8 pounds of pulp in Pen II. However, each pound of gain cost 5 cents in the beet fed lot and the dressed pork cost 6.8 cents per pound. In this trial, then, the pulp gave a better return in dollars and cents than the sugar beets. It is believed the results would have been still more favorable to the pulp if we had fed only one-half as much, or three and one-half pounds instead of seven pounds, which was consumed per day. The beet fed lot actually ate three and three-fourths pounds of beets per day.

The pigs in Pen III. ate 5.4 pounds of corn for each pound of gain, making the cost of each pound of gain 7 cents, or 8 cents per pound for dressed pork.

The pigs in Pen IV. ate only 4.5 pounds of grain composed of equal parts of wheat and barley for each pound of gain, at a cost of 4.5 cents, or of 6.1 cents for each pound of dressed pork. These pigs grew better and dressed better than those fed on corn alone. (See illustration.) This shows that one pound of wheat and barley was equal to 1.2 pounds of corn for making gains, where the corn is fed alone. But since corn cost $1.30 per hundred pounds while the wheat and barley cost only $1.00 per hundred pounds, there is even greater difference in the respective values of the dressed pork produced. If wheat and barley were worth $1.00, then in the light of this experiment the farmer could not afford to pay more than 83.3 cents for corn if he contemplated feeding it alone to swine as is usual. Instead of that, many farmers paid 46 cents to over 50 cents per hundred more for corn than it was worth to them and even sold their other grains to enable them to do it.

Comparing the values of pulp with grain in Pens II. and IV., we see that eight pounds of pulp in Pen II. was made

to take the place of 0.6 pounds of grain in Pen IV. This would give the pulp a value of $1.50 per ton when wheat and barley were worth $1.00 per hundred pounds. It was noticed that the pigs given pulp and beets in Pens II. and V. made much larger growth of frame than those in the other pens. This is nicely shown in the photograph here reproduced, of the representative pigs of Pens III., IV. and V., and indicates that such ration given to young pigs during the first feeding period may produce larger ultimate gains and have a greater value than is here indicated where they were also used in the last fattening period.

Comparing the foods given to pigs in Pens IV. and V., it is evident that 4 pounds of sugar beets in Pen V. took the place of 0.3 pounds of grain in Pen IV. This shows the sugar beets to have a value of $1.50 per ton when mixed with grain for pig feeding, or exactly the same value which we obtained for the pulp. It is not unlikely that different values might have been obtained if different proportions of these foods were given, but we would feel safe in advising any farmer not to pay $4.50 or $5.00 per ton for beets for feeding to swine. It is altogether probable that the beets were more valuable than this for sheep and cattle which naturally require a more bulky ration than hogs can profitably use. A bulletin reporting experiments to show the value of beets and pulp when fed to cows has been published, and another reporting experiments with lambs is now ready for press. These publications should be consulted by intending feeders.

PIG FEEDING EXPERIMENTS OF 1900-1901.

ADDING ROUGHAGE OR ROOTS TO A RATION.

An experiment to indicate whether dry alfalfa roughage could be given a place in a ration for swine, was begun on December 1st, 1900. Nine Berkshire pigs were divided into three lots of three each and fed rations of mixed grain, mixed grain and dry alfalfa hay, and mixed grain and sugar beets. The mixed grain consisted approximately of two parts of corn and one of barley. The pigs would not eat the dry alfalfa at first, but they were made to eat it by chopping the hay rather fine and mixing with barley slop.

The pigs were thrifty Berkshires raised on the College farm and were given a value of 4 cents per pound at the beginning of the experiment. The corn was worth 80 cents per hundred pounds and the ground barley $1.05 per hundred pounds. The pigs were fed 97 days and their value is given at five cents per pound live weight at the end of the fattening period.

Table VIII. gives the kinds of food eaten, the average amount of each food consumed by each pig in the ninety-seven days, the live weight at the beginning and end of the experiment, and the average dressed weight.

TABLE VIII.

AVERAGE FOOD, WEIGHT AND GAIN PER HEAD.

	Average Food Eaten.				Average Weight.			Percent Dressed Weight.
	Corn.	Barley.	Sugar Beets.	Alfalfa.	At Beginning.	At End.	Gain.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	%
Pen I..........	409.50	190.70		55.30	162.20	272.30	101.10	86.10
Pen II.........	381.30	173.50			154.70	259.70	105.00	87.40
Pen III........	350.30	184.30	99.30		148.30	244.70	96.40	87.10

In addition to their grain ration the pigs in Pen I. consumed an average of 55.3 pounds of dry alfalfa hay, a little more than one-half pound per day. They made the best gain but did not dress quite as well as the pigs in the other pens. Those in Pen III. ate approximately one pound of sugar beets apiece per day in addition to the grain ration, but they made the poorest gains.

In Table IX. is given the average food eaten for each pound of gain produced, the average gains made, and the comparative cost and profit. In Pen I. it took 5.44 pounds of grain and .49 pounds of alfalfa to make a pound of gain, and while the pigs in this lot made the best gains on account of the food eaten, it was at a slightly greater cost than where grain was fed alone in Pen II. With the corn and barley mixture it seems that it took a large amount of grain for each pound of gain, not making as good a showing as did wheat and barley in other experiments. While only a small amount of sugar beets was eaten by the pigs in Pen III., adding beets to the ration seemed to produce no beneficial effect. The pigs made smaller gains at greater expense that either of the other lots.

TABLE IX.

FOOD PER POUND OF GAIN, COST AND PROFIT.

	Average Food for One Pound Gain.				Gain per Head per Day.	Cost per Pound of Gain.	Aver'ge Cost of Food Eaten.	Aver'ge First Cost of Hogs @ 4 cts.	Aver'ge Total Profit @ 5 cts.	Aver'ge Cost per lb. of Dress'd Pork.
	Corn.	Barley.	Sugar Beets.	Alfalfa.						
	lbs.	lbs.	lbs.	lbs.	lbs.	cts.	$	$	$	cts.
Pen I......	3.72	1.72		0.49	1.13	4.9	5.40	6.49	1.73	5.10
Pen II.....	3.63	1.65			1.08	4.6	4.86	6.18	1.94	4.90
Pen III....	3.64	1.91	1.03		.99	5.2	5.04	5.93	1.26	5.30

SWINE FEEDING EXPERIMENT OF 1901.

An experiment planned to test the value of shorts when fed with corn and to compare the value of a ration of corn with a combination of wheat, oats and barley with the value of a ration of shorts fed in a like combination. The feeding was done from March 23d to May 31, 1901. Eleven pure bred Berkshire pigs were used in this experiment, averaging about five months of age. The trial was conducted similar in all respects to the other experiments reported in this bulletin. The following foods were fed:

Pen I.—Corn.

Pen II.—Corn and shorts.

Pen III.—Shorts, wheat, oats and barley fed in rotation. Shorts with wheat and oats one day, and with wheat and barley the next, oats and barley the third day and so on.

Pen IV.—Corn, wheat, oats and barley. The corn rotated with two other grains as indicated for pigs in Pen III.

In Pen I. there were two pigs averaging 164.5 pounds. They were two months older than the remaining ones used

in the experiment and weighed a little over sixty pounds over the average in the other pens. The three pigs in each of the remaining pens were quite evenly divided as to age, size, etc.

The following prices were charged in computing the results of the experiment:

Corn, 83 cents per cwt.
Shorts, 75 cents per cwt.
Wheat, 95 cents per cwt.
Oats, $1.20 per cwt.
Barley, $1.20 per cwt.

Table X. gives the average food eaten by each animal in the respective pens, the average weight and gain of same, and the percent each dressed.

TABLE X.

AVERAGE FOOD, WEIGHT AND GAIN PER HEAD.

	Average Food Eaten.					Average Weight.			Percent Dressed Weight.
	Corn.	Shorts.	Wheat.	Oats.	Barley.	At Beginning.	At End.	Gain.	
Pen I.	lbs. 423.25	lbs.	lbs.	lbs.	lbs.	lbs. 164.50	lbs. 230.00	lbs. 65.50	78.60
Pen II.	227.00	221.66				104.00	177.60	73.30	77.40
Pen III.		226.50	76.50	73.60	75.50	112.50	188.20	88.20	81.60
Pen IV.	208.60		72.30	68.50	68.30	98.00	185.30	85.60	79.20

TABLE XI.

FOOD FOR ONE POUND GAIN, COST AND PROFIT.

	Average Food for One Pound of Gain.					Gain per head per day	Cost per pound of grain.	Av. cost of food eaten.	Av. 1st cost of hogs @ 4 cts.	Av. total profit @ 5 cts.	Av. cost per lb. of dressed pork
	Corn.	Shorts.	Wheat.	Oats.	Barley.						
Pen I.	lbs. 6.43	lbs.	lbs.	lbs.	lbs.	lbs. .98	cts. 5.30	$ 3.51	$ 6.58	$ 1.41	cts. 4.03
Pen II.	3.08	3.01				1.11	4.80	3.54	4.16	1.18	4.33
Pen III.		2.61	0.88	0.85	0.87	1.31	4.70	4.22	4.50	0.69	4.20
Pen IV.	2.43		0.84	0.80	0.80	1.27	4.70	4.06	3.92	1.19	4.35

Table XI. gives the details of the food eaten for each pound of gain and cost and the profit. The results corres-

pond with those reported on other experiments in this bulletin, in showing that corn alone is not a balanced ration and does not produce the gains that result from feeding other grains with or without corn. This is not so apparent at first from this table as it is after carefully studying the conditions and results.

The pigs in Pen I. were older and larger than those in the other pens. It took 6.43 pounds of corn to produce a pound of gain and their average gain per day was only .98 pounds, compared with much larger gains in the other pens. The cost per pound of gain is high, but the apparent profit and cost per pound of dressed meat is low. This is because they were 64 pounds heavier than the other pigs and at the increase of one cent per pound this weight makes the apparent profit 64 cents higher that it should be when compared with the smaller pigs in the other pens. The real profit in such comparison would be 97 cents instead of $1.41 as actually shown in the table. The cost of one pound of dressed meat figured on the basis of these smaller 100 pound pigs in the other lots, would be 5.77 cents instead of 4.03 cents, and the corn ration would be the most expensive one in this series. This shows the fallacy of figuring all of the pigs at the same price at the beginning of the experiment, regardless of size and age, and illustrates the advantage of selecting larger animals for feeding. With this understanding it appears that mixed grain was superior in every case to corn alone.

The gains per day increased with the increase in the variety of food eaten, and the amount of grain for each pound of gain decreased with the same condition. In Pen I. it took 6.43 pounds of corn for each pound of gain; in Pen II. 6.09 pounds of corn and shorts per pound of gain; in Pen III. 5.31 pounds of mixed grain per pound of gain. In Pen IV. 4.87 pounds mixed grain per pound of gain. Comparing Pens III. and IV. gives an idea of the comparative value of corn and wheat shorts. It took more shorts with other grains in Pen III. to produce a pound of gain than it did corn with other grains in Pen IV. and although the shorts were figured at a less price than corn, the total profit from the pen is less than—approximately one-half—that in Pen IV.

It is likely that the ration given in Pen III is as much too narrow as the corn ration in Pen I. is too wide. The nutritive ratio of corn is about 1:9.4, and of the ratio in Pen III. is 1:5.9. The nutritive ratio called for in the German feeding standard for fattening hogs is 1:7. The nutritive

ratio of the ration given Pen II. is 1:6.3 and that supplied Pen IV. is 1:8.1. The best gains, and for the least amount of food, were made in Pen IV. This study is interesting when compared with the wheat and barley ration fed in the first experiment reported in this bulletin. Equal parts of wheat and barley have a nutritive ratio very near the German standard and have produced the best results for us. Other factors probably influence the effect of a ration as much as will small differences in the ratio. The cost and profit is influenced by the prices of the different grains so it is not so good a measure of the actual fattening quality of the mixtures.

The results in Pen IV. show that 4.87 pounds of grain used was worth as much as 6.43 pounds of corn in Pen I. This grain mixture consisted of 2.44 pounds of wheat, oats and barley, equal parts, and 2.43 pounds of corn. Then if corn is worth 83 cents per hundred pounds, the wheat, oats and barley to mix with it in this fattening ration were worth $1.36 per hundred. At the present prices farmers could not afford to feed corn at all and it would be better to eliminate the oats from the ration, feeding wheat and barley as indicated in the first experiment reported in this bulletin. All these experiments show the advantage of our home grown grains in unmistakable terms.

GENERAL CONCLUSIONS.

The salient points shown in the series of pig feeding experiments reported in this bulletin are briefly:

1. Home grown grains fed in proper proportion to balance the ration are more valuable than corn.
2. A well balanced ration gives better returns in every case than a poorly balanced ration, and a mixture of grains is better than a single grain fed alone.
3. Sugar beets for swine feeding were unprofitable with us, either fed alone or in combination with grain. Green pasture would probably serve the purpose of furnishing succulent food for growing pigs at less expense.
4. Sugar beets are little more than a maintenance ration when fed alone to hogs.
5. Sugar beets and sugar beet pulp proved equally valuable in our experiments and because of its cheapness and effect on growth we believe pulp may be profitable to feed to growing pigs in connection with a grain ration, or during the first part of a fattening period.

6. These experiments indicate that sugar beets may have a value of about $1.50 per ton when fed to hogs in combination with grain.
7. Beet pulp gave a return of $1.50 per ton when fed in combination with grain.
8. Sugar beet pulp served the same purpose in our hog rations as did sugar beets and at less expense.
9. It was necessary to mix beet pulp with grain in order to educate the pigs to eat it. We would not recommend feeding more than two pounds of pulp to a pound of grain in a ration for pigs which are from 100 to 200 pounds in weight.
10. Our trials indicate that pigs take some of the nutritive property from beets, but their principal use, as well as that of pulp, seems to be mechanical.
11. Dry alfalfa hay as roughage, may be made use of by the growing pigs. In our trials the pigs ate more grain and made more gain than on a similar grain ration minus the alfalfa.
12. Comparing our results with pig feeding experiments in other states, indicates that our small grains, more especially our barley and wheat, are worth more compared with corn than similar grains raised under rainfall conditions.
13. Mixed wheat and barley ground together make a well balanced ration for pigs and one upon which they will make better growth and gain than they will on a ration composed of corn alone. The farmer in Colorado cannot ordinarily afford to sell his home grown grain and purchase corn for fattening hogs. Wheat and barley in equal parts were worth 17 percent more than corn fed alone.
14. If wheat and barley are worth $1.00 per 100 pounds, corn is worth only 83.3 cents, but many farmers sold their home grown grains for $1.00 to purchase corn at $1.30.
15. There is enough food at home, including grain, alfalfa pasture, by-products of dairies and beet sugar factories, to make swine growing and fattening a profitable industry on Colorado farms.

EXPRESS BOOK PRINT
FORT COLLINS, COLO

Bulletin 75. September, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

LAMB FEEDING EXPERIMENTS.

1900-1902.

I. SUGAR BEETS AND BEET PULP.

II. HOME GROWN GRAINS AND CORN.

III. (*a*) SMALL GRAINS AND CORN.

(*b*) WARM AND COLD WATER.

(*c*) SHROPSHIRE GRADES AND NATIVE LAMBS.

—BY—

B. C. BUFFUM and C. J. GRIFFITH.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

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FORT COLLINS, COLORADO.

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PLATE I.

Fed Oats, Wheat, Barley and Alfalfa.
Given Cold Water to Drink.

PLATE II.

Fed Oats, Wheat, Barley and Alfalfa.
Given Warm Water to Drink.

LAMB FEEDING EXPERIMENTS.

BY B. C. BUFFUM AND C. J. GRIFFITH.*

The value of the by-products from the beet sugar factories is a prominent subject among lamb feeders. With the remarkable growth of the beet industry within the state there will be a corresponding increase in the tonnage of pulp available to feeders. The pulp sells at a low price per ton, so low indeed that if it has any virtue at all either for fattening or for preparing the lambs to make more profitable gains when put on full feed, it will be a valuable addition to our supply of stock food in Colorado.

To compare the value of pulp when fed with alfalfa, or with alfalfa and grain, and the value of sugar beets when fed in the same manner, we carried out an experiment at the College during the past spring. The pulp was furnished gratis for this purpose by the Great Western Sugar Company at Loveland, through the courtesy of Mr. A. V. Officer. Early in February a car load of pulp was received and hauled to the College barn where it was placed in convenient piles on the ground near the feeding pens.

Much has been written and said during the past year about the value of beet pulp, and many of the statements have been extravagant, or were without any basis of fact. It is not our intention to put any account of the feeding of pulp which has been complied from other sources in the body of this bulletin, but will state simply our own results. In our bulletin No. 73 of this Station, on the "Feeding Value of Beet Pulp and Feeding Sugar Beets and Pulp to Cows," has been published a brief resume of such data as we consider authentic, compiled from all sources to which we have had access. Our tests of sugar beet pulp for fattening hogs are reported in Bulletin No. 74 on "Swine Feeding in Colorado." This last bulletin gives the only information with which we are acquainted on feeding beet pulp to swine.

*Instructor in Animal Husbandry.

Many of our farmers have been convinced of the great worth of sugar beets in a ration for fattening stock, and in some instances they have paid more for beets for feeding than the factory would pay for manufacturing purposes. This makes the question of the value of sugar beets for feeding a live one, and we here report experiments which were carried out to throw light on this subject.

Sugar beets for fattening hogs were tried last year, and the results indicated that they were not so valuable for that purpose as many have supposed. These experiments are reported in the bulletin on "Swine Feeding in Colorado." It is well known, however, that a food suitable for one class of stock may not be suitable for another, and the results obtained with beets or pulp when fed to swine do not indicate what their nutritive quality would be when fed to lambs or cattle. Pigs require a concentrated ration, and while they may be, and in our trials were, able to live and make small gains when fed with beets alone, the ration was a bulky one and did not prove profitable. Pigs do not ordinarily live on dry hay, while lambs or cattle may lay on fat with such bulky rations, making good returns for the roughage consumed. Feeding beets or pulp to lambs along with alfalfa is very different from feeding these products to pigs when given either with or without grains or other concentrated foods.

The second experiment reported was inaugurated to compare home grown or small grains with corn, which is shipped in in great quantities by our sheep feeders, and during the past year, at least, has cost them much more than the grains which they raise on their own farms could be sold for. Many have an idea that stock of any kind cannot be fattened and properly fitted for market without using corn. Investigations in eastern states have shown that wheat is as valuable as corn for fattening stock. Our own experiments with fattening swine reported in the bulletin entitled "Swine Feeding in Colorado," show that mixtures of wheat and barley are preferable to corn for fattening pigs when either grain can be obtained at the same price as corn.

Occasionally there is introduced into the state, something new, either a new grain or a new variety which is given notoriety through the papers and which many go to considerable expense to obtain before they can know much about it. The Russian Spelt or Emmer is one of these, and in our sheep feeding trials its value has been carefully investigated. Russian Spelt, as it is popularly called (more

accurately "emmer"), is a primitive sort of wheat which does not shell out of the hull when threshed. As the kernels remain in the chaff, the grain is lighter than wheat, weighing about the same per bushel as oats, but it produces large yields and is said to be a good drouth resistant variety. In 1901, a field of this spelt on the College farm yielded sixty-three bushels per acre. The grain is very hardy. The present season we have a field of emmer growing on very poor land which is somewhat alkalized, parts of which would heretofore produce nothing but a crop of poverty weed. On this land we will get a very fair crop of grain.

The third experiment given in this bulletin was planned along the same line as the second one reported—a comparison of home grown grains with corn. Cold water was also compared with warm water in this same trial. A third comparison made in this experiment was the relative gain made by Shropshire crosses and native western lambs. These so-called Shropshire crosses were the first cross of pure bred Shropshire bucks on the native merino grade ewes. They were raised at the College farm from some old native ewes which had been purchased for an experiment.

Seven years ago the Station published Bulletin No. 32 on "Sheep Feeding in Colorado," prepared by Professor W. W. Cooke. That bulletin contains some information of general value and some interesting feeding experiments are reported. Those who are making a study of the lamb feeding problem will be interested enough to compare the results reported at that time and those given in the present bulletin, more especially, perhaps, the results from feeding sugar beets. The cost for each pound of gain where beets formed a portion of the ration was higher than the cost per pound of gain with grain rations, and the profit was not sufficiently large to make beet feeding remunerative. Professor Cooke reported a maximum return from feeding beets of $2.77 per ton and gives a low value of grain when added to a beet ration. The investigations reported in the present bulletin tend to substantiate that view. Because of the low cost of beet pulp, however, it forms a cheap substitute for the more expensive roots and the pulp seems to serve the purpose of adding a succulent food so well that there is considerable advantage to be gained from its proper use.

The comparative value of wheat and corn for lamb feeding where the lambs are finished on either of these grains, as reported in Bulletin No. 32, shows wheat to be

worth 15 percent more than corn, but under other conditions and for the entire trials then made, the wheat and corn were almost exactly equal to each other. The results with corn in our more recent trials show that the high prices paid by our farmers for corn during the past year were more than it was actually worth when compared with our home grown grains at their prevailing market prices. The high prices received for fattened lambs made the feeding of corn at $1.30 per hundred pounds profitable, but the man who properly fed wheat and barley at one cent per pound would have an appreciably larger balance on the right side of his ledger. It is the province of the Experiment Station to investigate these subjects and furnish the information to all who desire it. In addition to Bulletin No. 32 on sheep feeding, the Station has published Bulletin No. 52 on "Pasturing Sheep on Alfalfa and Raising Early Lambs."

EXPERIMENT 1.--SUGAR BEETS AND BEET PULP.

KIND OF LAMBS FED.

In the first and second experiments here reported, we used Mexican lambs which averaged 55 pounds per head March 5th, 1902. They were in very poor condition when we received them, a few days prior to the beginning of the experiment. They had trailed a long distance to Albuquerque, New Mexico, at which place they were held until they could be dipped twice. During the interval between the dippings they were kept on the sand hills where there was practically no food to be had. This class of lambs would represent the most unprofitable kind that could be had for feeding anywhere in the west. The resulting profit obtained, then, may be considered a minimum In April the lambs were shorn and the wool credited at ten cents per pound.

OBJECT AND PLAN OF EXPERIMENT I.

The object of this trial was to determine the comparative value of sugar beets and beet pulp when fed with alfalfa hay either alone or in combination with grain. Fifty lambs had been divided into ten lots of five each and five of these lots were to receive beet and pulp rations. Lots I. to IV. are regularly reported. Lot X. was given a ration of beets, grain and straw, in order to show the comparative return from feeding alfalfa and to determine whether the beets and straw could be made to take the place of alfalfa. Some of our farmers have thought that sugar beets had such a high feeding value that they could be made to take the place largely of both hay and grain. We failed to get the lambs in Lot X. fat enough to turn and considered the trial so much out of the ordinary that it would not be worth while to compare the results more than in a general way. So this lot does not appear in our tables. The following rations were fed to those in the sugar beet and pulp trial:

Lot I.—Alfalfa and beet pulp.

Lot II.—Alfalfa and beet pulp with grain consisting of equal parts of barley and wheat added during the last eight

weeks the lambs were fed; cutting off all the pulp during the last thirty days.

Lot III.—Alfalfa and sugar beets.

Lot IV.—Alfalfa and sugar beets with grain consisting of equal parts of wheat and barley added during the last eight weeks the lambs were on feed, cutting off the supply of sugar beets during the last thirty days.

The alfalfa was fed *ad libitum*, a complete record being kept of amount of fed and amount not eaten. It was the intention to feed all the pulp and beets that the lambs would eat, but it was not kept before them all the time.

Each lamb was marked, and weighed separately once a week in order to keep complete individual records of them as well as accounts of the lots. The lambs were selected carefully in order that there should be no advantage of any one lot over another by having in it a superior class of individuals.

In Experiments I. and II., the feeding was done and the notes taken by senior students under the direction and supervision of one of us. Our acknowledgments are due more especially to Mr. E. P. Taylor and Mr. H. J. Faulkner.

In computing comparative values and the cost of food eaten, cost for each pound of gain, etc., local market prices of the food used are as follows:

Alfalfa on the farm, $4.00 per ton.

Beet pulp delivered, $1.00 per ton.

Sugar beets on the farm, $4.00 per ton.

Wheat and barley, $1.00 per hundred pounds.

RESULTS OF EXPERIMENT I.

Nothing occurred to mar or interfere with this experiment except the necessity of feeding a small amount of grain during the first week to induce the lambs to begin eating the pulp and beets at once and a mistake which was made during the last three weeks when Lot III. receiving the beets were given grain. As all the lots received the same amount of grain the first week, the value of the comparisons of one lot with another are not disturbed. By drawing the conclusions for the first five weeks and for the first ten weeks, we are able to eliminate the effect of the grain given during the last thirty days to the pulp and beet lots, and show the comparative value of beets and pulp.

The beets showed a tendency to scour the lambs when they ate too large a quantity of them. The lambs in Lot IV. and one lamb, No. 7, in Lot II., were out of condition

once during the feeding period by having been fed too liberally.

Table I. gives the amounts of food supplied to each lot during each week, with the total amount fed each lot and the orts not eaten which were weighed back each day.

TABLE I.

LAMB FEEDING. SUGAR BEETS AND BEET PULP.
FOOD EATEN IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Pulp	Pulp Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Pulp	Pulp Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Sugar Beets	Sugar Beet Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Sugar Beets	Sugar Beet Orts	Alfalfa	Alfalfa Orts	Barley and Wheat
Mar. 5 to Mar. 12	107	40	96	32	8.0	103	53	96	42	8	81	15	96	38	8	75	31	96	32	8
Mar. 12 to Mar. 15	42	2	36	12	....	42	14	36	9	...	42	2	36	14	...	42	3	36	19	...
Mar. 15 to Mar. 22	102	4	84	29	....	102	7	84	22	...	98	3	84	33	...	98	5	84	45	...
Mar. 22 to Mar. 29	124	5	84	19	..	124	1	84	20	...	94	4	84	27	...	104	...	84	23	...
Mar. 29 to April 5	132	9	84	22	....	132	5	84	15	...	108	1	84	21	...	108	...	84	26	...
April 5 to April 12	142	10	84	20	....	97	...	84	15	18	112	2	84	24	...	79	...	84	19	17
April 12 to April 19	147	6	84	24	....	94	...	84	32	22	128	...	84	37	...	97	...	84	25	23
April 19 to April 26	147	8	112	39	.	94	1	84	18	33	140	...	84	18	...	97	...	84	18	33
April 26 to May 3	193	4	112	35	...	90	37	94	40	47	151	3	94	27	...	84	6	91	40	51
May 3 to May 10	280	10	112	11	....	...	...	98	20	51	160	...	98	12	...	...	...	98	11	60
May 10 to May 17	272	21	112	32	5.5	...	...	98	22	49	39	...	102	23	31	...	...	98	21	73
May 17 to May 24	217	38	113	30	6.0	...	...	98	41	45	18	...	112	41	63	...	...	98	28	81
May 24 to May 28	90	22	45	7	....	...	...	40	8	29	....	...	45	6	26	...	...	40	8	30
Totals	1974	199	1155	314	19.5	878	113	1164	279	302	1166	30	1087	321	128	784	45	1061	315	376

Table II. gives the average amount of food actually consumed by each lamb daily. The alfalfa left uneaten

consisted of the coarser stems and these were consumed readily by the stock sheep. It was necessary at first to sprinkle the pulp with grain in order to get the lambs to eat it at all. Near the end of the trial the supply of sugar beets gave out and a little grain was added to the ration given Lot III.

TABLE II.

AVERAGE FOOD EATEN DAILY IN POUNDS.

	Alfalfa.	Pulp.	Sugar Beets.	Wheat and Barley.	Total Food Daily.
Lot I.	2.02	4.22		0.04	6.28
Lot II.	2.10	1.82		0.72	4.64
Lot III.	1.82		2.70	0.30	4.82
Lot IV.	1.77		1.76	0.90	4.43

The amount of alfalfa, pulp and grain consumed by the five lambs in Lot I. was 6.28 pounds per head daily; 2.02 pounds of alfalfa, 4.22 pounds of pulp and .04 pounds of grain; or a total of 168.2 pounds of alfalfa, 375 pounds of pulp and 3.9 pounds of grain per head during the 84 days feeding.

Lot III. ate a ration of 1.82 pounds of alfalfa, 2.70 pounds of sugar beets and .30 pounds of grain per head daily, making a total ration of 4.82 pounds consumed daily; or a total amount of food eaten per lamb through the experiment of 153.2 pounds of alfalfa, 227.2 pounds of sugar beets and 25.6 pounds of grain.

There were 2.10 pounds of alfalfa, 1.82 pounds of pulp and .72 pounds of grain consumed daily by the average lamb in Lot II., a total daily food of 4.64 pounds, or a total through the period of 177 pounds of alfalfa, 153 pounds of pulp, and 6.04 pounds of grain.

Lot IV. consumed an average daily ration of 1.77 pounds of alfalfa, 1.76 pounds of sugar beets and .90 pounds of wheat and barley, a total daily ration of 4.43 pounds per lamb. This makes a total of 149.2 pounds of alfalfa, 147.2 pounds of sugar beets, and 75.2 pounds of grain consumed through the experiment by the average lamb in this lot.

The total amounts of food consumed for the entire period are as we should expect to find them, greater in those lots having pulp than in those having the beets, probably because of the greater percent of nutrients in the beets.

WEIGHT AND GAINS PER WEEK ON PULP AND BEET RATIONS.

Table III. gives by weeks the individual weights of the lambs in the four lots during the trial, and the total gain

made by each. Lamb No. 4 in Lot I. did poorly, making a gain of only eight pounds for the whole time, while the other four lambs in the pen made an average of 17 pounds each. For the first five weeks while on pulp and alfalfa the other four lambs in Lot I. made average gains of 9.7 pounds, while lamb No. 4 gained only three pounds. This lamb making a gain so much smaller than the normal will explain in part at least the difference in gains of Lot I. and

TABLE III.

INDIVIDUAL WEIGHTS AND GAINS IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
Tag No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
March 5	61	53	57	53	60	59	64	58	54	54	60	39	52	56	52	69	57	60	54	49
March 12	68	54	60	58	64	64	69	61	60	63	60	47	56	58	57	73	63	64	60	55
March 15	66	57	61	56	65	63	67	60	60	61	61	45	58	58	57	77	68	67	60	59
March 22	68	57	63	55	67	64	69	63	62	64	64	51	59	61	59	75	63	64	63	52
March 29	67	59	63	53	71	67	64	63	66	68	65	52	61	63	62	77	70	61	64	55
April 5	71	62	64	56	73	69	69	64	65	73	68	56	65	65	64	79	72	65	66	56
April 12	69	62	65	57	74	71	70	62	67	75	66	56	65	67	66	80	76	67	68	59
Sheared **April 19**	67	61	64	56	74	70	68	64	66	75	67	58	65	64	61	78	77	69	68	55
April 26	70	63	66	55	82	75	71	64	70	79	69	59	68	66	65	83	75	72	73	61
May 3	74	69	69	53	85	77	73	69	68	78	71	63	73	68	69	86	83	75	75	60
May 10	75	69	70	62	83	78	73	71	72	77	72	63	70	69	71	84	87	78	78	65
May 17	74	71	71	60	84	74	74	71	74	81	77	61	72	69	74	87	89	78	81	68
May 24	77	72	73	62	86	80	78	73	73	83	78	63	75	71	77	90	90	82	80	71
May 28	74	71	72	61	82	80	77	72	73	81	78	68	74	69	76	90	87	82	79	72
Fleece	4	3	3	4	2	4	4	2	4	3	4	2	3	4	3	6	2	2	3	4
Total Gain	17	21	18	12	24	25	17	16	23	30	22	31	25	17	27	27	32	24	28	27

Lot II. during the first five weeks when both lots were receiving the same ration of pulp and hay.

TABLE IV.

POUNDS GAIN PER WEEK—WITHOUT GRAIN.

	Lot I.*	Lot II.*	Lot III.†	Lot IV.†
March 8	20	28	19	26
March 15	1	6	1	16
March 22	5	11	15	-11
March 29	3	6	9	7
April 5	13	12	15	11
Gain	42	51	59	49

*Lots I. and II. fed pulp and alfalfa.
†Lots III. and IV. fed beets and alfalfa.

TABLE V.

POUNDS GAIN PER WEEK—WITH GRAIN.

	Lot I.*	Lot II.†	Lot III.‡	Lot IV.§
April 12	1	5	2	12
April 19	11	15	11	14
April 26	14	16	12	17
May 3	14	6	17	15
May 10	9	6	1	13
May 17	1	3	8	11
May 24	10	13	11	10
May 28	-10	-4	1	-3
Gain	50	60	63	89
Total Gain Flesh (March 8–May 28)	76	94	106	121
Fleece	16	17	16	17
Total Gain with Fleece Mar. 8–May 28)	92	111	122	138

*Lot I. fed pulp and alfalfa.
†Lot II. fed pulp, alfalfa and grain.
‡Lot III. fed beets, alfalfa (grain three weeks.)
§Lot IV. fed beets, alfalfa and grain.

Table IV. shows that the ten lambs of Lots I. and II. fed pulp and alfalfa for five weeks gained 93 pounds. In order to get the lambs to eat the pulp 16 pounds of grain was mixed with it for the two lots during the first week, and during this time while receiving the grain they made a total gain of 38 pounds, leaving 55 pounds gain due to the pulp and alfalfa fed the other four weeks.

Lots III. and IV. consisted of 10 lambs fed on sugar beets and alfalfa, and they gained 108 pounds during the first five weeks. They were fed the same amount of grain during the first week as Lots I. and II. The gains made by the 10 lambs fed with beets during the first week amounted to 45 pounds, leaving 63 pounds of gain due to sugar beets and alfalfa in the remaining four weeks, or eight pounds more gain for the beets than for the pulp.

Table V. shows that the five lambs in Lot I. made a total gain of 92 pounds, 16 pounds of which was fleece, while those fed beets and alfalfa made a total gain of 122 pounds, 16 pounds of which was fleece. However, the beet fed lambs received 99 pounds of grain more than those which were fed pulp. The pulp fed lambs in Lot I. were given 11½ pounds of grain in the two weeks from May 10 to May 24, and Lot III. which was fed beets received 120 pounds of grain during the last three weeks of the experiment.

In our plan of the experiment it was not the intention that the pulp and beet fed lambs should have any grain at all.

Referring to Table V. it will be seen that the pulp fed lambs made but one pound gain during the last three weeks, while the beet fed lambs made an appreciable gain during this time when the grain was given them. The gain made by Lot III. during the last three weeks was 20 pounds, but during this time they received only 57 pounds of beets, and the principal part of the gain was due, no doubt, to the grain fed.

Lot III., fed beets and alfalfa, gained 122 pounds during the experiment, 16 pounds of which was fleece. Deducting the 20 pounds gain while being fed grain, and the amount of fleece, and comparing with Lot II., the results would indicate that the beet and alfalfa lot gained 10 pounds more than the lot which received pulp and alfalfa. This statement must be taken with due allowance because the five lambs ate almost two and one-half pounds of beets per day during the last three weeks and they may have produced an appreciable effect on the gains.

Lot II., which was fed pulp, alfalfa and grain, gained 111 pounds, 17 pounds of which was fleece, and Lot IV. fed beets, alfalfa and grain, gained 138 pounds, 17 pounds of which was fleece. Then the lots fed beets and grain gained 27 pounds more than the lot fed pulp and grain, the fleece being the same in each case.

Adding grain to the pulp and alfalfa ration gives an increased gain of 10 pounds over the pulp and alfalfa ration during the last eight weeks of the experiment. No comparison can be made between the beet, alfalfa and grain ration and the beet and alfalfa ration for the whole time, because of the amount of grain given to Lot III. during the last three weeks. However, by taking the first 10 weeks of the feeding period, leaving out the last three weeks, we are able to make a fair comparison between the lots.

Briefly stated up to this time, (May 10), Lot I., on pulp, gained in flesh 75 pounds, Lot III., on beets, gained 86 pounds, or eleven pounds more for the beet ration than for the pulp ration. Lot II., fed pulp and grain, gained 82 pounds, or seven pounds more than those on pulp without grain, and four pounds less than Lot III. on beets and alfalfa. Lot IV., on beets and grain, gained 103 pounds for this ten weeks' period, or 28 pounds more than Lot I. on pulp; 27 pounds more than those on beets and alfalfa, and 21 pounds more than those on pulp and grain.

For the ten weeks' period Lot I. ate 1277 pounds of pulp and 640 pounds of hay worth $1.82. Lot III. ate 1079 pounds of beets and 577 pounds of hay worth $3.31. The beet lot gained 11 pounds more than the pulp lot, worth 66 cents. Then $1.82 worth of pulp and hay was equal to $2.65 worth of beets and hay when fed without grain. The hay being the same, the pulp would be worth $1.46 per ton compared with beets at $4.00 per ton when fed with hay alone. There was actually more hay eaten with the pulp than with the beets so the difference would not be quite so great. Making the same comparison between the lots which were fed grain with pulp and with beets, Lot II. ate in the ten weeks 765 pounds of pulp, 720 pounds of hay and 179 pounds of grain, while Lot IV. ate 784 pounds of beets, 566 pounds of alfalfa and 192 pounds of grain. The food eaten by Lot II. was worth $3.62 and that eaten by Lot IV. was worth $4.62. Lot IV. gained 21 pounds more than Lot II. which was worth $1.26. Then $3.62 worth of pulp, alfalfa and grain was equal to $3.36 worth of beets, alfalfa and grain. The beets would be worth a little more than

TABLE VI.

FOOD EATEN AND GAINS IN POUNDS.

	No. lambs	No. dys fed	Food Eaten					Average Weight		Total gain flesh	Fleece
			Alfalfa	Sugar Beets	Pulp	Wheat	Barley	At be-gin'ing	At end		
Lot I......	5	84	841	....	1775	9.75	9.75	56.8	72.2	76.0	16.0
Lot II.	5	84	885	....	765	151.00	151.00	57.8	76.6	94.0	17.0
Lot III ..	5	84	766	1136	....	64.00	64.00	51.8	73.0	106.0	16.0
Lot IV ...	5	84	746	739	......	188.00	188.00	57.8	82.0	121.0	17.0

$4.00 per ton compared with pulp at $1.00 per ton when fed in this way with grain at one cent per pound.

The whole discussion indicates that so far as the results of this experiment are reliable, pulp at $1.00 per ton, with alfalfa at $4.00 per ton, is a much more economical ration than beets at $4.00 per ton, with hay at the same price, when no grain is given, but that a ration of pulp, alfalfa and grain is approximately equal to beets, alfalfa and grain at $1.00 and $4.00 per ton respectively.

Table VI. gives the total amount of food eaten by each lot and the gains made.

AMOUNT AND COST OF FOOD COMPARED WITH GAINS.

Table VII. gives the amount and cost of food consumed for one pound of gain made in each lot, also the average percent of dressed weight for the respective lots.

TABLE VII.

FOOD EATEN FOR ONE POUND GAIN.

	Food for One Pound Gain					Cost 1 lb. Gain	Percent Dressed Weight
	Alfalfa	Sugar Beets	Pulp	Wheat	Barley		
	lbs.	lbs.	lbs.	lbs.	lbs.	cts.	
Lot I.......	9.14	....	19.30	0.02	0.02	2.83	45.7
Lot II.. ..	7.97	....	6.90	1.36	1.36	4.65	48.1
Lot III.....	6.28	9.31	....	0 52	0.52	4.16	46.6
Lot IV . .	5.40	5.35	....	1.36	1.36	4.87	46.6

Comparing Lots I. and II. we find that 9.14 pounds of alfalfa; 19.3 pounds of pulp, and .04 pounds of grain in Lot I. was equal to 7.97 pounds of alfalfa; 6.9 pounds of pulp and 2.72 pounds of grain in Lot II. In Lot III. where sugar beets took the place of the pulp in the ration of Lot I. it required 6.28 pounds of alfalfa, 9.31 pounds of beets and 1.04 pounds of grain to produce one pound of gain; or it took 9.31 pounds of beets and 1.00 pound of grain in Lot III. to replace 19.3 pounds of pulp and 2.86 pounds of alfalfa in Lot I.

Lot IV., which had a similar ration to Lot II., except that the pulp in Lot II. was replaced with with beets in Lot IV., required 5.4 pounds of alfalfa, 5.35 pounds of beets and 2.72 pounds of grain for one pound of gain. The extra

grain in Lot IV. of 1.68 pounds for each pound of gain replaced .88 pounds of alfalfa and 3.96 pounds of sugar beets in the ration of Lot III.

Because of the cheapness of the food the pulp and alfalfa made the gain cheaper than the other rations. The cost of each pound of gain was 2.83 cents in Lot I. fed pulp, 4.16 cents in Lot III. fed beets, 4.65 cents in Lot II. fed pulp and grain and 4.87 cents in Lot IV. fed beets and grain. As would be expected, the percent of dressed weight was smallest with the pulp fed lambs. They dressed out 45.7 percent of the live weight against 46.6 percent for the sugar beet lot, 48.1 percent for the pulp and grain lot and 46.6 percent for the beet and grain lot. The amount of alfalfa consumed for each pound of gain was greatest in the pulp fed lot and least with the lot fed beets and grain.

When the lambs were slaughtered pieces of the meat were sent to a number of people with the request that they furnish an opinion in regard to the quality of the mutton. With one exception all those who received the samples of mutton stated that the first piece, which was pulp and alfalfa fed, possessed good flavor and quality, but was not so fat as the second piece which was corn fed. The following letter from Mrs. Carpenter is typical of the general opinion. Those receiving the samples did not know what kind of food had been given the lambs:

"We received the two samples of mutton and I cooked them both by boiling. The flavor of the first piece was so delicate that it was hard to realize that it was mutton. Yet we liked the second piece better as it was fatter and juicier, and we prefer fat, juicy mutton. The flavor of the second piece was more like the mutton we are are accustomed to."

Note. Lot X. was fed straw, beets, wheat and barley and made a total gain of 74 pounds. They consumed 436 pounds of wheat and barley, worth $4.36, 683 pounds of sugar beets, worth $1.37, 512 pounds of straw which we will estimate at $1.00 per ton or 25.6 cents. The total cost for the food is $5.99. The value of the gain is 62 pounds of flesh at 6 cents, equals $3.72, and 12 pounds of fleece at 10 cents, $1.20, or $4.92. This gives a loss of $1.07, providing the lambs had been fit for market. As they were not fat enough to slaughter this does not express the total loss. The alfalfa, beet and grain ration in Lot IV. above gave a profit on the gain of $2.23. This forcibly illustrates the value of alfalfa and the fact that sugar beets must be supplemented with other nutritious roughage in order to give profitable returns.

PLATE III.

Fed Corn and Alfalfa.
Given Warm Water to Drink.

PLATE IV.

Fed Corn and Alfalfa.
Given Cold Water to Drink.

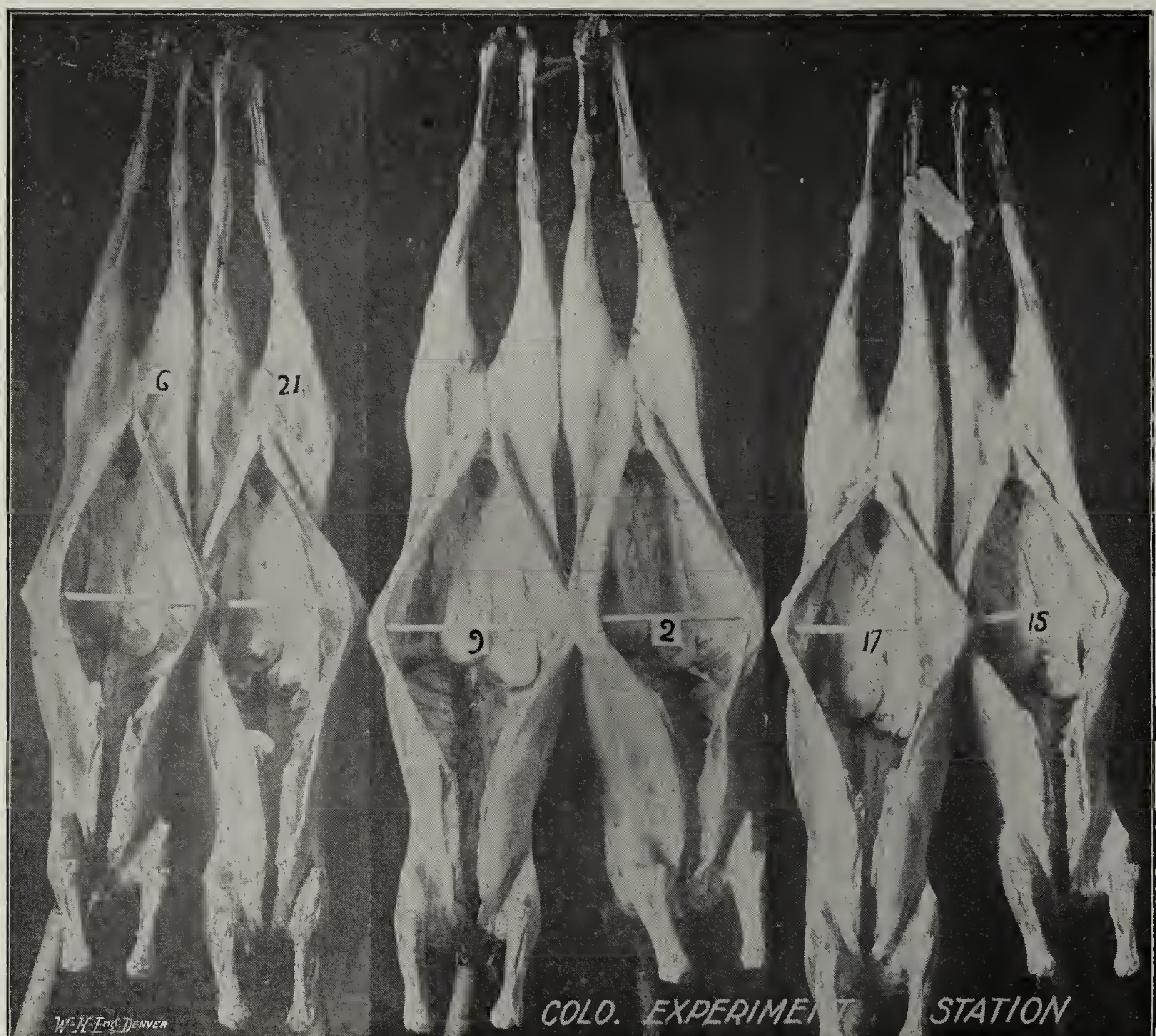

PLATE V.

Representative Carcasses of Lots I, II, III, IV and V.

COST AND PROFIT.

Table VIII. gives the cost and profit from feeding lambs with sugar beets and beet pulp rations. The estimate of profit is based on a price of six cents per pound for the gain made during the feeding period and is the comparative rather than the total profit. The total profit would vary with the first cost of the lambs and the selling price. Our lambs cost us almost five cents per pound, and if sold at an advance of one cent, or six cents per pound when fat, the profit would be increased by the cent per pound for the weight of the lambs when put on feed, or an average of about 55 cents, amounting to $2.75 more for the fat lambs in each pen than the profit indicated in the last column of the table.

TABLE VIII.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
Lot I......	Pulp, Alfalfa,	$ 2.76	cts. 2.83	$ 4.56	$ 1.60	$ 6.16	$ 3.40
Lot II.....	Pulp, Grain, Alfalfa	5.17	4.65	5.64	1.70	7.34	2.17
Lot III....	Beets, Alfalfa,*	5.08	4.16	6.36	1.60	7.96	2.88
Lot IV.....	Beets, Grain, Alfalfa	6.73	4.87	7.26	1.70	8.96	2.23

*Fed grain last three weeks.

The cost for each pound of gain was the lowest for Lot I. fed pulp and alfalfa. A good gain was made by this lot and the low cost of the food made the cost per pound of gain only 2.83 cents, while the total profit on the gain is $3.40 which is the highest return made by any lot in either experiment I. or experiment II. (See Table XV. Experiment II). While the profit was greater than that from any other lot their total gain and the per cent of dressed weight was lower than any of the others which might have produced an appreciable effect on their selling price in the open market. All the figures here given account for one day's shrinkage in the yards, but if shipped a long distance it is not unlikely that the shrinkage would be greater from the pulp fed lambs.

The next best profit was from Lot III. given sugar beets and alfalfa with some grain the last thirty days. This lot

ate less food and made larger gains than the pulp fed lambs, but the increased cost of food reduced the profit. Lot IV. fed beets and grain made a greater profit than Lot II fed pulp and grain, though the difference is small. The total value of the food steadily increases as the grain and beets are added to the ration, and the total gains made, also increase but not in proportion to the increased cost of food.

The object of lamb feeding in Colorado is to find a market for the surplus alfalfa and the profit for such feeding is often expressed by the value received for the hay so used. Then giving the other foods their local market values the hay made returns in this experiment of $12.20 per ton in Lot I.; $7.36 per ton in Lot II.; $9.86 per ton in Lot III. and $8.18 per ton in Lot IV. Giving the alfalfa a local value of $4.00 per ton on the farm, the profit for the gains made would show a return from feeding pulp with it in Lot I. of $4.28 per ton and $4.88 per ton on Lot II. Allowing $4.00 per ton for alfalfa and one cent per pound for the grain, the sugar beets made a return in Lot III. of $7.96 per ton and in Lot IV. the return from the beets would be $8.22 per ton. When one begins to compute returns made by any one food in this way he realizes at once that at best the results are only comparative. There is nothing to show that the food which appears to have given the return indicated actually did produce its proportion of the gain. Again the final value will vary greatly with the proportion of each food consumed in the ration. However, as a means of comparison it serves a purpose. The figures we have given show that pulp gave approximately one-half the return pound for pound that was obtained from beets, but because of its cheapness it gave an apparently large value for the hay fed with it in Lot I. All of our estimates of cost and profit are based on amount of food eaten and the value of the gain. This method is sufficient for reliable comparisons and is used with the assumption that the increased selling price over the price paid for feeders will meet all labor expense and necessary waste.

LAMB FEEDING EXPERIMENT NO. 2.

Experiment No. 2 was planned and carried out coincident with and as a part of Experiment No. 1. The lambs used in these trials were from the same flock. The separate lots in the two experiments were all selected at the same time in order to avoid as much as possible any error in individuality due to improper care in selecting. The object of this experiment was to compare our home grown grains and combinations of them with corn. These two experiments—first and second—having the same conditions throughout, and there being no apparent difference in the class of animals used, afford an excellent opportunity to check the comparative profits of pulp, sugar beets, corn and our home grown grains when fed with alfalfa for fattening lambs.

As stated before, these were Mexican lambs and were in very poor condition for that class. The returns then should represent the minimum profits at the price per pound allowed for the grain. In order to eliminate any confusing data the profits are figured on gain only and no attempt was made to show actual profits by taking into consideration the initial cost to us and the final income when the lambs were sold. The lambs in both these experiments were treated alike in everything except the kinds of food given. They were fed and watered at regular hours, twice each day, and the waste not eaten was weighed back daily. The lambs were sheared during the week, April 12th to April 19th and the wool credited to them at the selling price, which was ten cents per pound. Careful notes were kept to put on record complete information of the progress of the experiment. No unusual incidents or accidents occurred which would seriously mar the experiment. Lamb No. 37 in Lot VIII. became entangled in the fence and was found dead the morning of the day the other lambs were slaughtered. His live weight at the end of the previous week having been secured, and the fact that the gain for the last week so nearly offset the shrinkage during the last twenty-four hours when they were off feed, makes no correction necessary in reporting the results. The per cent of dressed weight for Lot VIII. is averaged for four instead of for five lambs.

April 10th lamb No. 43 in Lot IX. dropped a buck lamb which was taken away and she was allowed to remain on

feed until the end of the experiment. She did so poorly, however, that in order to compare this lot with the others in profits, the averages for Lot IX. are taken from the remaining four lambs as indicated by foot notes in the tables when the correction is necessary.

TABLE IX.

FOOD EATEN, IN POUNDS.

	Lot V.			Lot VI.			Lot VII.			Lot VIII.			Lot IX.		
	Corn	Alfalfa	Alfalfa Orts......	Spelt or Emmer...	Alfalfa	Alfalfa Orts......	Barley	Alfalfa	Alfalfa Orts......	Wheat and Barley.	Alfalfa	Alfalfa Orts......	Wheat and Emmer	Alfalfa	Alfalfa Orts......
March 5—March 8.....	6.9	52	24	6.9	52	22	6.9	52	10	6.9	52	10	6.9	52	13
March 8—March 15....	17.5	105	46	17.5	105	45	17.5	105	38	17.5	105	48	17.5	105	43
March 15—March 22...	19.4	97	41	19.4	97	42	19.4	97	42	19.4	97	44	19.4	97	41
March 22—March 29...	21.9	114	54	21.9	114	51	21.9	114	45	21.9	114	53	21.9	114	50
March 29—April 5.....	23.1	120	53	23.1	120	51	23.1	120	51	23.1	120	54	23.1	120	52
April 5—April 12......	26.2	122	58	26.2	122	53	26.2	122	52	26.2	122	61	26.2	122	57
April 12—April 19.....	26.2	122	55	26.2	122	49	26.2	122	49	26.2	131	53	26.2	122	60
April 19—April 26.....	32.5	132	55	32.5	132	46	32.5	132	47	32.5	132	57	32.5	132	54
April 26—May 3.......	36.2	136	67	36.2	135	56	36.2	135	55	36.2	135	81	36.2	135	67
May 3—May 10.........	40.0	117	44	40.0	117	35	40.0	117	39	40.0	117	64	40.0	117	55
May 10—May 17........	48.8	130	76	48.8	130	62	48.8	130	67	41.1	130	54	48.8	130	74
May 17—May 24........	43.7	106	55	43.8	106	40	43.7	106	46	43.7	106	59	43.7	106	53
May 24—May 31........	43.7	105	47	43.7	105	36	43.7	105	46	43.7	105	58	43.7	105	56
May 31—June 6........	15.9	37	18	43.7	37	17	15.9	37	19	63.6	136	54	49.8	106	55
Totals	402.0	1495	693	430.0	1494	605	402.0	1494	606	442.0	1602	750	436.0	1563	730

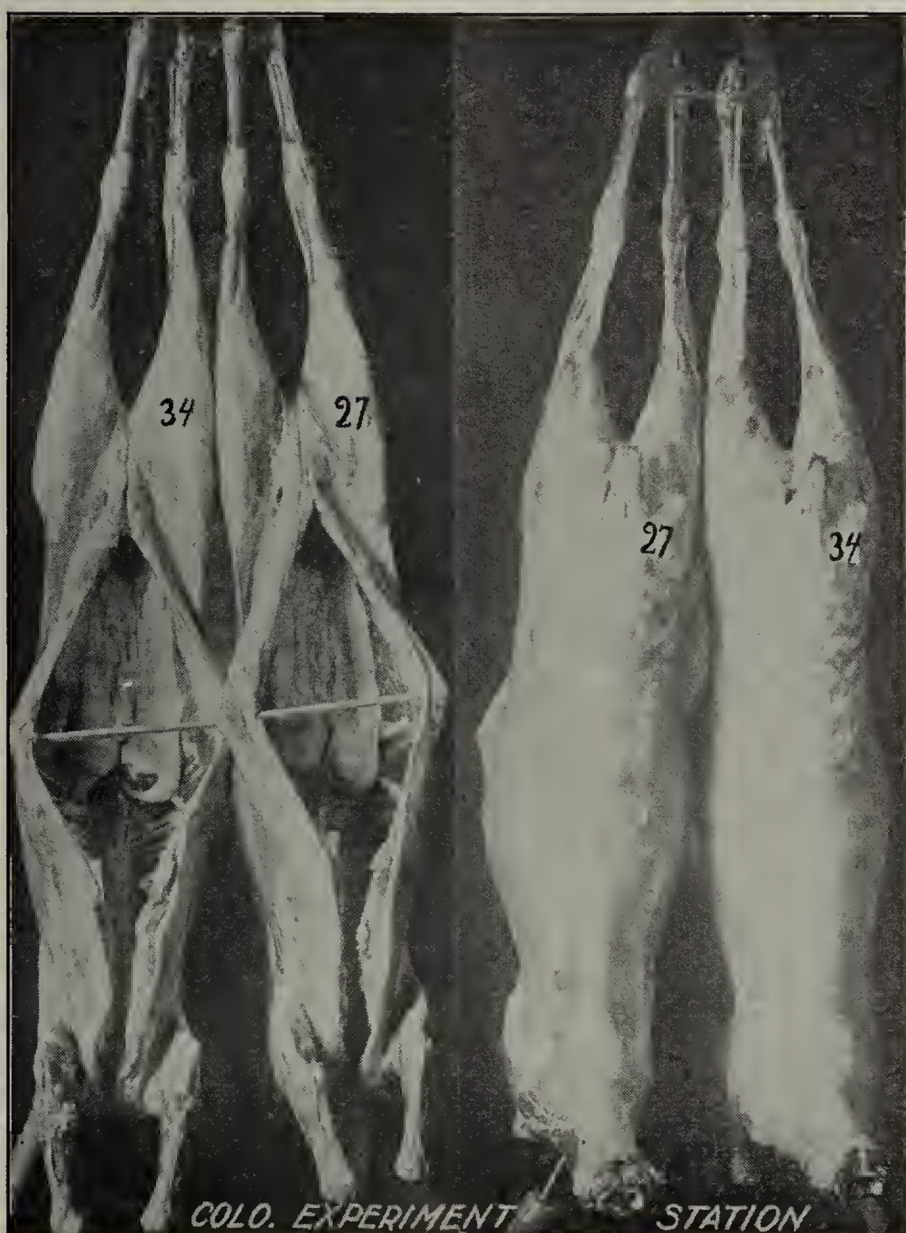

PLATE VI.

Representative Carcasses of Lots VI and VII.

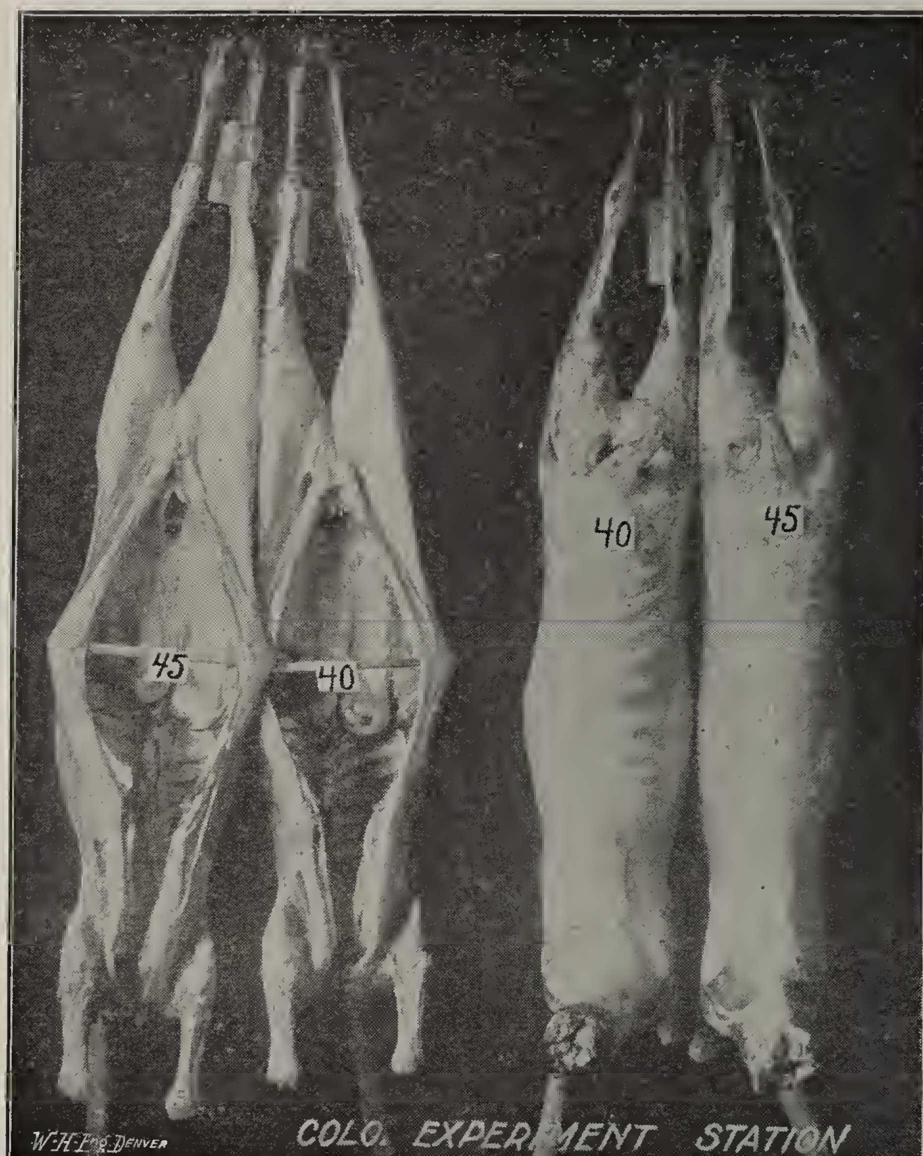

PLATE VII.

Representative Carcasses of Lots VIII and IX.

PLAN OF EXPERIMENT NO. 2.

The plan of the experiment was as follows:

Lot V. was fed corn and alfalfa.

Lot VI. was fed spelt (emmer) and alfalfa.

Lot VII. was fed barley and alfalfa.

Lot VIII. was fed wheat, barley and alfalfa, the wheat and barley in equal amounts.

Lot IX. was fed wheat, spelt, (emmer) and alfalfa, the wheat and spelt in equal amounts.

Lots V., VI. and VII. were fed ninety days. Lots VIII. and IX. ninety-five days.

The alfalfa was fed in such quantities that it would be before the lambs all the time. The corn and other grains were fed in small quantities at first, increasing the amount gradually to one and one-quarter and one and one-half pounds daily per lamb. The larger amount was fed only a short time. The feed was charged at local prices, which were at the time of the experiment $4.00 per ton for alfalfa on the farm, $1.30 per hundred pounds for corn, and one cent per pound for the wheat, barley and spelt.

Table IX. shows the amount of food given each lot for periods of one week, also the total amounts given each lot and the amount of waste. This table shows the details of the feeding, the increase in the gain, and any irregularity which may have occurred in the appetites of the animals.

Table X. shows the average amount of each kind of food and the total daily consumption by each lamb. Lot VI. fed alfalfa and spelt, ate more food than any of the others, although the total daily consumption of food differs little in any of the lots. The lambs in Lot IX. ate less alfalfa than those in any of the other lots, and less total food daily. They were given wheat and spelt, which could

TABLE X.

AVERAGE FOOD EATEN DAILY, IN POUNDS.

	Alfalfa.	Corn.	Wheat.	Barley.	Spelt.	Total Food.
Lot V	1.78	0.88	....	....	....	2.66
Lot VI	1.97	....	....	....	0.95	2.92
Lot VII	1.96	....	....	0.88	....	2.84
Lot VIII	1.80	....	0.465	0.465	....	2.73
Lot IX	1.75	....	0.459	....	0.459	2.67

hardly be considered a variety of food because the spelt is a wheat, differing from the common variety principally in the chaff which encloses the spelt kernels. The lambs got off feed more quickly on this ration than on any other and made comparatively poor gains.

TABLE XI.

INDIVIDUAL WEIGHTS AND GAINS, IN POUNDS.

	Lot V.					Lot VI.					Lot VII.					Lot VIII.					Lot IX.				
Tag No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
March 5	55	58	53	54	49	56	50	55	54	54	59	58	58	58	54	51	43	48	44	50	61	54	55	52	62
March 8	59	68	57	57	53	57	59	62	60	64	62	63	63	63	63	50	51	50	49	52	65	58	60	55	67
March 15	65	72	65	60	56	65	60	65	63	62	69	64	62	64	62	57	54	59	56	60	67	60	65	54	69
March 22	64	71	63	60	57	61	61	65	63	60	66	62	63	61	63	54	54	57	55	59	66	57	64	53	61
March 29	67	76	65	60	61	66	63	68	66	63	68	67	68	67	68	54	59	61	59	63	69	60	69	56	69
April 5	69	80	69	65	64	62	66	71	68	66	72	68	70	68	68	63	61	62	60	65	71	64	72	58	72
April 12	68	80	65	63	64	71	65	69	66	66	68	67	69	70	66	61	60	62	60	66	72	63	66	58	72
April 19	63	76	62	64	59	67	65	67	64	62	64	67	69	67	62	66	62	61	59	64	71	58	55	56	68
April 26	66	81	65	68	62	70	65	70	68	64	68	68	70	69	68	64	64	63	60	66	73	61	57	58	70
May 3	72	88	63	76	67	76	75	74	73	68	76	75	74	75	74	68	63	62	62	70	76	60	61	63	75
May 10	70	82	68	73	66	78	75	80	74	69	74	75	77	74	74	70	69	69	65	75	79	68	63	64	78
May 17	68	84	68	75	68	78	72	79	72	70	72	70	76	71	72	64	65	60	59	69	65	65	56	59	72
May 24	73	88	69	75	69	78	75	81	74	71	73	74	76	72	77	70	68	61	62	75	79	66	58	64	77
May 31	75	91	74	78	74	82	80	84	77	75	75	75	79	76	79	76	71	69	65	75	82	67	59	64	76
June 3	76	81	73	79	73	82	77	84	78	75	76	76	79	75	78	75	died	66	65	76	82	69	60	71	77
Fleece	2	3	5	3	4	3	3	4	2	3	3	3	5	3	6	3	1	3	4	3	2	4	3	2	3
Total Gain	23	26	25	28	28	29	30	33	26	24	20	21	26	20	30	27	29	21	25	29	23	19	8	21	18

WEIGHTS AND GAINS PER WEEK—CORN AND SMALL GRAINS.

Table XI. reports the individual weights and gains made by each lamb. The weights for April 19th were made after shearing, and the apparent loss that week is due to the removal of the fleece.

Lamb No. 43 in Lot IX. is one previously spoken of which it is necessary to drop out in making the final averages. All the others make fair gains.

Table XII. gives the gain or loss each week for the five lambs in each lot.

TABLE XII.

POUNDS GAIN PER WEEK.

	Lot V.	Lot VI.	Lot VII.	Lot VIII.	Lot IX.
March 8	25	33	27	16	21
March 15	24	13	7	34	10
March 22	-3	-5	-6	-7	14
March 29	14	16	23	17	22
April 5	18	7	8	15	14
April 12	-7	4	-6	-2	-6
April 19	1	3	9	17	-9
April 26	18	12	14	5	11
May 3	24	29	31	8	16
May 10	-7	10	0	23	17
May 17	4	-5	-13	-31	-35
May 24	11	8	11	19	27
May 31	18	19	12	20	4
June 9	-10	-2	0	-3	11
Total Gain Flesh	113	127	97	117	75
Fleece	17	15	20	14	14
Total Gain with Fleece	130	142	117	131	89

The losses on April 19th were due to taking away the fleece that week. There is much variation in the gains week by week. The table shows that all the lambs except those in Lot V. lost weight during the week of May 10th to 17th. This was evidently due to the over feeding of grain. On May 9th the ration of grain was increased in all the lots, from one to one and one-quarter pounds per head daily to one and one-half pounds per head. Our notes show that during this week the lambs refused to eat up all of their grain. This was especially true with Lots VIII. and IX. where wheat was a part of the ration. The ration was reduced to one and one-quarter pounds daily per lamb on May 16th, and all the lambs again began to make gains. Corresponding losses, but not in quite such a marked degree, seemed to have occurred during the third and sixth weeks after the lambs were put on feed. The largest total gain

was made by Lot VI. which received the spelt ration and the smallest gain was made by Lot IX. which was fed wheat and spelt.

FOOD EATEN AND GAINS MADE.

Table XIII. gives the total amount of each kind of food eaten, the initial average weight of the lambs in each lot, and the total gain. The weights and gains in Lot IX. are computed from the averages of the four lambs which made normal gains during the feeding period.

TABLE XIII.

FOOD EATEN AND GAINS, IN POUNDS.

	No. of Lambs.	No. Days Fed..	Food Eaten.					Average Weight		Total gain flesh	Fleece........
			Alfalfa.	Corn...	Wheat.	Barley.	Spelt..	At Beginning	At End		
Lot V....................	5	90	803	402	......	......	......	53.8	78.4	113.	17
Lot VI	5	90	889	......	......	......	430	53.8	78.2	127.0	15
Lot VII................	5	90	888	......	......	402	......	57.4	76.8	97.0	20
Lot VIII...............	5	95	852	...,	221	221	... ..	47.2	70.6	117.0	14
Lot IX	5	95	833	......	218	......	218	*57.5	*75.0	**87.5	14

*Average of four lambs.
**Estimated gain of five lambs from averages of four.

TABLE XIV.

FOOD EATEN FOR ONE POUND GAIN.

	Food for One Pound Gain.					Cost 1 lb. Gain	Percent Dressed Weight
	Alfalfa	Corn	Wheat	Barley	Spelt		
Lot V	lbs. 6.17	lbs. 3.09	lbs.	lbs.	lbs.	cts. 5.25	52.1
Lot VI	6.26	....	....	....	3.03	4.28	49.2
Lot VII	7.59	....	....	3.43	....	4.95	48.8
Lot VIII.................	6.50	....	1.69	1.69	....	4.68	49.6
Lot IX	8.20	....	2.14	....	2.14	5.93	59.0

Table XIV. gives the amount of each kind of food eaten for each pound of gain produced and the per cent of dressed weight, with the cost of each pound of gain. There is a marked variation in the per cent of dressed weight. Lot IX. dressed 59 per cent and Lot VII. 48.8 per cent, a difference of over 10 per cent. This condition would have much to do with their value on the market and those with the low per cent of dressed weight would give less profit.

The best general result was obtained with the spelt and alfalfa ration fed to Lot VI. These lambs consumed 6.26 pounds of alfalfa and 3.30 pounds of spelt at a cost of 4.28 cents for each pound of gain. This is very close to the amount of hay and corn for each pound of gain, but because of the high price of corn, which cost us $1.30 per hundred pounds, the cost of each pound of gain was nearly one cent higher than in the spelt ration. If corn was obtained for $1.00, which was the price allowed for the spelt, the cost of each pound of gain would be 4.32 cents, or within .04 cents of the cost of each pound of gain with the spelt ration. This difference is very small and the corn ration lambs dressed almost three percent better than the spelt ration lambs.

The next best result was obtained with Lot VIII. fed wheat, barley and alfalfa. These lambs ate 6.5 pounds of alfalfa and 3.38 pounds of grain composed of equal parts of wheat and barley, for each pound of gain, making the gain cost 4.68 cents per pound. At the same price the corn ration would have produced a little cheaper gain than this, but the farmer could not afford to sell his wheat and barley

TABLE XV.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
Lot V......	Corn, Alfalfa,	$ 6.83	cts. 5.25	$ 6.78	$ 1.70	$ 8.48	$ 1.65
Lot VI.....	Spelt, Alfalfa,	6.08	4.28	7.62	1.50	9.12	3.04
Lot VII....	Barley, Alfalfa,	5.80	4.95	5.82	2.00	7.82	2.02
Lot VIII...	Wheat, Barley, Alfalfa,	6.12	4.68	7.02	1.40	8.42	2.30
Lot IX.....	Wheat, Spelt, Alfalfa	6.13	5.93	5.25	1.40	6.65	.52

or spelt at one cent a pound and pay the prices which prevailed for corn the past year.

COST AND PROFIT.

Table XV. presents the results of the experiment in the dollars and cents form.

Here is given the cost of food consumed by each lot of five lambs, the value of gain made at six cents per pound, and the total profit on the gains. As before stated, this profit would be increased by the amount of the increased price of the fat lambs over the original cost of the feeders, and the cost would be increased by adding the cost of labor, interest on the investment, etc. Here again the best results were obtained from spelt and alfalfa, the total profit being $3.04. The next best results were obtained with Lot VIII., fed wheat and barley, which produced a profit of $2.30. Lot VII., fed on barley and alfalfa, gave a profit of $2.02, and the profit with the corn and alfalfa fed lot was $1.65. Lot IX., fed wheat and spelt, produced a profit of only 52 cents, probably because this ration was not well balanced.

Had the corn been obtained at the same price as other grains, $1.00 per hundred, the total profit from Lot V. would have been $2.86. This is still not so good a profit as was produced by the spelt ration, but was better than the other grains or combinations of them used in this series of experiments.

It would appear from comparisons of Lots V. and VIII. that when wheat and barley are worth $1.00 per cwt., corn would be worth approximately $1.11 per hundred pounds. This experiment indicates that spelt has a high feeding value, but it would hardly be safe to recommend it without reservation from a single experiment. Further trial will be made with it in the near future. Computing the value of spelt from this experiment, compared with wheat and barley at $1.00 per hundred pounds, it would appear to have a value of $1.13 per hundred, or two cents per hundred more than corn.

Crediting all the profit to the alfalfa as we did in Experiment I., we have a return for the alfalfa fed to Lot V. of $6.42 per ton. The profit on Lot VI. would give the alfalfa a value of $9.48 per ton, Lot VII. $6.77 per ton, Lot VIII. $8.00 per ton, Lot IX. $4.19 per ton.

Comparing profits in Experiment I. and Experiment II., which cover the nine lots of lambs, we have the largest profit from Lot I., fed pulp and alfalfa, and the second best

profit from Lot VI., fed spelt and alfalfa. The third best combination of foods seems to be that given to Lot III., which was fed beets and alfalfa and a small ration of grain during the last thirty days. The wheat and barley gave us slightly better profit than the lot fed pulp, grain and alfalfa. The corn ration gave a lower profit than either of the lots fed pulp or beets with or without grain.

LAMB FEEDING EXPERIMENT NO. 3,

COMPARISON OF HOME GROWN GRAINS WITH CORN, WARM AND COLD WATER. SHROPSHIRE GRADES AND NATIVE LAMBS.

OBJECT AND PLAN OF EXPERIMENT.

During the winter of 1900-01 an experiment was planned to test the value of a mixture of home grown grains compared with corn for fattening lambs, and to determine whether or not there would be any advantage in giving lambs warm water to drink instead of cold water. For this purpose twenty western lambs, half of them Shropshire crosses raised on the College farm, were divided into four lots of five each and given the following rations:

Lot I. was given an equal mixture of oats, wheat and barley with alfalfa and cold water.

Lot II. was fed the same as Lot I., excepting warm water (80-100 F.) was given twice daily instead of cold water.

Lot III. was fed corn, alfalfa and warm water.

Lot IV. was fed the same as Lot III., except cold water was given in place of warm water.

Each lamb was marked with an ear tag and weighed separately once a week. Each lot of lambs was given an equal amount of shed room and the same sized yard to run in, and were treated alike in every respect. Grain, hay and water were supplied twice daily and the orts were weighed back daily. Previous to the time the experiment was begun the lambs had been fed alfalfa and a very small amount of grain, and were in a good thrifty growing condition. One half pound of grain per head was fed daily the first week and this amount was increased to three-quarters of a pound the second week. The grain was gradually increased until March 16, when they were receiving one and three-fourths pounds per head per day.

The prices of food used in this experiment were as follows:

Alfalfa hay on the farm, $4.00 per ton.

Corn, local market, $0.80 per hundred pounds.

Wheat, oats and barley, $1.00 per hundred pounds.

Table XVI. gives for periods of one week, the amounts of the different rations fed and the orts weighed back.

TABLE XVI.

FOOD EATEN, IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Oats, Wheat, Barley	Alfalfa.......	Alfalfa Orts.....	Water.......	Water Orts......	Oats, Wheat, Barley	Alfalfa......	Alfalfa Orts.....	Warm Water.....	Warm Water Orts,	Corn..........	Alfalfa.......	Alfalfa Orts.....	Warm Water.....	Warm Water Orts,	Corn	Alfalfa........	Alfalfa Orts......	Water..........	Water Orts......
Jan 23-30.........	17	96	27	233	60	17	95	21	233	33	17	96	19	233	50	17	96	24	233	50
Jan. 30-Feb. 7...	26	90	13	185	41	26	90	17	185	18	26	90	17	185	21	26	90	17	185	28
Feb. 7-13.........	35	105	28	210	29	35	105	25	210	27	35	105	24	210	26	35	105	26	210	37
Feb. 13-20.......	44	103	27	210	43	44	103	30	210	29	44	103	28	210	20	44	103	30	210	30
Feb. 20-27........	52	91	24	210	22	52	91	28	210	35	52	91	24	210	21	52	91	24	210	31
Feb. 27-Mar. 7...	61	104	38	240	36	61	104	30	240	77	61	104	28	240	23	61	104	29	240	60
Mar. 7-14........	56	91	30	225	29	56	91	24	225	43	56	91	26	225	27	56	91	21	225	47
Mar. 14-21.......	60	91	52	245	40	60	91	54	245	53	60	91	45	245	31	60	91	58	245	58
Mar. 21-28.......	61	91	39	241	37	61	91	42	241	34	61	91	35	241	26	61	91	52	241	38
Mar. 28-Apr. 4...	61	89	37	245	72	61	91	38	245	48	61	91	31	245	36	24	81	33	245	99
Apr 4-11........	49	70	32	245	84	59	84	36	245	48	54	91	15	245	33	41	70	23	245	98
Apr. 11-18.......	49	70	28	245	81	49	70	42	245	99	52	91	40	245	64	45	70	27	245	107
Apr. 18-25...... ..	49	70	21	245	73	49	70	34	245	82	31	70	26	245	66	45	70	23	245	72
Apr. 25-May 2...	10	40	26	137	26	13	45	43	139	50	22	45	32	145	47	22	45	33	137	46
Totals...........	630	1201	422	3116	673	643	1221	484	3118	676	632	1250	390	3124	491	589	1198	420	3116	802
Totals for 4 sheep Jan. 23-May 2.....	536	1091	355	2672	593	538	1014	403	2620	589	518	1123	326	2597	414	509	1026	363	2717	727

FOOD AND WATER CONSUMED.

One ewe was thrown out of each lot on account of dropping a lamb; from Lot I. on April 4, Lot II. on April 11,

Lot III. on April 17, and Lot IV. on March 27. The "totals for four sheep" at the bottom of the table are corrected totals, and the ones from which the results are computed. Since one lamb was thrown out of each lot the results are all computed by using averages of the remaining four lambs.

The lambs in Lots I. and II. ate more of the mixed grains than the lambs in Lots III. and IV. ate of corn. The corn fed lots in turn consumed more alfalfa than the grain fed lots. The water drank by the two grain lots and that drank by the two corn lots is practically equal. The two lots which were given warm water drank 145 pounds in excess of that drank by the two lots which received cold water. This would be and average of one-fifth of a pint per head daily.

Table XVII. gives the average amounts of food and water actually consumed by each lamb daily.

Lots I. and II. ate more of the mixed grain daily than Lots III. and IV. ate of corn, but the grain fed lots ate a little less hay per day than the corn fed lots.

TABLE XVII.

AVERAGE FOOD EATEN DAILY, IN POUNDS.

	Water.	Alfalfa.	Corn.	Mixed Grain.	Total Food
Lot I	5.17	1.85		1.35	3.20
Lot II	5.12	1.54		1.36	2.80
Lot III	5.51	2.01	1.30		3.31
Lot IV	5.02	1.67	1.28		2.95

WEIGHTS AND GAINS.

Table XVIII. gives the individual weights and gains for each week while the lambs were on feed. This table also gives the amount of wool produced by each lamb, and the total gain including the fleece. The Shropshire crosses are indicated in the table and enable comparison to be made between them and the western lambs.

It will be noticed that the Shropshire crosses made much better individual gains than did the other lambs. The two Shropshire crosses in Lot I. made an average total gain of 35.5 pounds, which was the same as the gains made by the other two lambs. In Lot II. the two Shropshire crosses made an average total gain of 36.5 pounds, and the other two lambs gained an average of 26.5 pounds.

In Lot III. the three Shropshire crosses made an average total gain of 40.6 (plus) pounds, and the other lamb made a total gain of 36 pounds.

In Lot IV. the two Shropshire crosses made an average total gain of 43 pounds, the other two lambs an average gain of 29 pounds.

TABLE XVIII.

INDIVIDUAL WEIGHTS AND GAINS, IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Shrop Cross..				Shrop Cross..		Shrop Cross..	Shrop Cross..			Shrop Cross..			Shrop Cross..	Shrop Cross..		Shrop Cross..			Shrop Cross..
Tag No..................	594	666	669	674	682	670	673	675	679	683	663	664	681	685	591	593	668	678	684	686
January 23..............	55	109	81	81	85	74	92	97	78	96	80	91	96	93	66	71	84	90	92	92
January 30..............	55	110	83	82	89	75	90	99	79	97	81	92	98	94	68	71	85	92	94	94
February 7..............	57	114	83	86	90	79	93	101	80	103	84	94	102	98	68	76	92	98	95	96
February 13.............	62	118	86	90	94	80	95	102	80	107	87	99	104	101	70	77	94	99	101	97
February 20.............	64	121	91	93	95	82	95	106	87	110	90	103	111	107	74	81	97	104	105	100
February 27.............	67	126	90	97	97	84	99	110	87	115	9	106	111	110	81	84	101	109	110	104
March 7.................	72	131	94	97	103	88	104	116	89	118	97	112	114	113	85	86	105	112	113	108
March 14................	74	136	94	103	106	90	108	119	92	124	98	117	120	115	90	88	109	116	117	112
March 21................	77	138	105	106	110	91	110	124	91	126	102	122	124	120	94	90	112	118	121	115
March 28................	81	147	104	111	112	93	115	128	96	135	105	129	128	122	102	94	119	120	128	118
April 4.................	85	150	102	114	115	95	116	133	98	136	106	133	129	120	101	93	114	117	*	116
April 11................	88	*	109	119	114	102	122	139	103	*	110	138	133	127	108	98	124	125	*	124
April 18................	90	*	114	122	122	103	123	136	104	*	112	*	137	129	109	100	125	126	*	126
April 25................	86	*	105	111	115	93	115	131	95	*	103	*	125	122	102	93	119	115	*	119
May 2...................	89	*	104	113	110	96	121	125	90	*	109	*	121	119	110	91	122	112	*	122
Fleece..................	4		7	9	8	10	7	9	9		8		11	9	6	5	9	11		9
Total Gain..............	38		30	41	33	32	36	37	21		37		36	35	50	25	17	32		39

*Thrown out.

The nine Shropshire crosses in the experiment averaged 39.1 pounds gain. The seven native lambs averaged 31 pounds gain, or 21.8 percent less than the Shropshire crosses. This shows the advantage of good blood, and of a mutton cross on the native sheep to produce profitable feeders. The Shropshire grades averaged 7.7 pounds of fleece, and the native lambs averaged nine pounds of fleece.

The table indicates that the lambs made remarkably even gains.

Table XIX. gives the pounds gain per week by each lot. There are some variations week by week, but the weeks which record losses are few. Except in the final week of the experiment, when the weights were taken after 24 hours shrinkage with the lambs off feed, there are but two instances of recorded loss of weight, both of them in the corn fed lots. The gains for May 2d were from the final live weight of the lambs after they had been off feed and water for twenty-four hours.

TABLE XIX.

POUNDS GAIN PER WEEK.

	Lot I.	Lot II.	Lot III.	Lot IV.
January 30	7	2	6	5
February 7	7	10	11	20
February 13	16	4	10	5
February 20	11	10	20	15
February 27	8	13	12	16
March 7	15	17	15	13
March 14	11	12	14	14
March 21	21	7	17	10
March 28	10	16	17	16
April 4	8	10	1	–11
April 11	14	24	22	31
April 18	18	0	9	6
April 25	–3	3	–1	3
May 2	–1	–2	7	1
Total Gain Flesh	114	91	124	110
Fleece	28	35	32	34
Total Gain with Fleece	142	126	156	144

Lot III. fed corn, alfalfa and given warm water to drink made the largest total gain. Lot IV., fed the same ration as Lot III., except that they were given cold water to drink, made the second largest gain. Then followed Lot I. and II. in order. The average total gain of Lots I. and II., the mixed grain lots, is 134 pounds; the average total gain of Lots III. and IV., the corn fed lots, is 151 pounds, or an average of 17 pounds more of the four lambs in the corn fed lots than in the two mixed grain lots. As shown in Table XX., Lot I. given cold water, gained 16

pounds in excess of Lot II., given the same ration, but having warm water instead of cold water. Lot III., given the same ration as Lot IV., except they were given warm water to drink, gained 14 pounds more. Warm water appeared to have the advantage in the latter lots, but in the former the greater gain was made when cold water was given.

If then warm water had any effect either way, there are other conditions which obscured the results.

AMOUNT AND COST OF FOOD COMPARED WITH GAINS.

Table XX. gives the total amount of food eaten and water drank and the total gain made by each lot during the experiment. By the use of this table the feeder can compute for himself the cost of food and value of gains under his own conditions.

TABLE XX.

FOOD, WATER AND GAIN IN POUNDS.

	No. of Lambs.	No. Days Fed.	Food Eaten and Water Drank.				Average Weight.		Total gain flesh	Fleece.......
			Alfalfa	Mixed Grains	Corn.	Water Drank	At Begin'ing	At End		
Lot I........................	4	99	736	536		2079	75.50	104.0	114	28
Lot II........	4	99	611	538		2031	85.25	108.0	91	35
Lot III......................	4	99	797		518	2183	83.75	114.75	124	32
Lot IV.......................	4	99	663		509	1990	84.25	111.75	110	34

The corn fed lots show a total average gain of 151 pounds, which is to be compared with a total average gain of 134 pounds in the small grain lots. For this gain it took an average of 513.5 pounds of corn in Lots III. and IV., and 537 pounds of oats, wheat and barley in Lots I. and II.

In Table XXI. will be found the amount of food eaten to produce each pound of gain, the cost of each pound of gain and the average percent of dressed weight in each of the trials. As no effect can be traced to the warmth of the water supplied we may average the results from Lots I. and II. fed the grain mixture, and those of Lots III. and IV. fed corn. Then with the corn ration it took 4.89 pounds of alfalfa and 3.37 pounds of corn to produce each pound of gain at an average cost of 3.67 cents. With the home grown grain mixture it took 5.01 pounds of alfalfa and 4.02 pounds

of grain to produce each pound of gain at a cost of 5.02 cents. The corn fed lots made an average dressed weight one and one-half percent higher than the small grain fed lots. Then the alfalfa eaten is so nearly equal in each lot, we may say that 100 pounds of corn was equal in fattening value to 119 pounds of wheat, oats and barley.

TABLE XXI.

FOOD EATEN FOR ONE POUND GAIN.

	Food and Water for One Pound Gain.				Cost 1 lb. Gain.	Percent Dressed Weight.
	Alfalfa.	Mixed Grains.	Corn.	Water.		
	lbs.	lbs.	lbs,	lbs.	cts.	
Lot I..	5.18	3.77		14.64	4.81	63.4
Lot II	4.84	4.27		16.12	5.24	61.2
Lot III	5.17		3.21	14.17	3.60	63.2
Lot IV	4.60		3.53	13.82	3.74	64.7

COST AND PROFIT.

The comparative cost and profit of the different lots is obtained by figuring the gain made at six cents per pound and the wool produced at 10 cents per pound. This gives the total value of the gain from which is subtracted the cost of the food consumed. There is a marked difference in the cost of the food for the different lots even when fed on the same ration. Referring to Table XXII. it will be noted that Lot I. ate 23 cents worth more of food per lamb than Lot II., although both were fed the same ration of grain,

TABLE XXII.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
Lot I......	Cold Water, Alfalfa, Mixed Grain	$ 6.83	cts. 4.81	$ 6.84	$ 2.80	$ 9.64	$ 2.81
Lot II.....	Warm Water, Alfalfa, Mixed Grain	6.60	5.24	5.46	3.50	8.96	2.30
Lot III....	Warm Water, Alfalfa and Corn.	5.73	3.60	7.44	3.20	10.64	4.91
Lot IV.....	Cold Water, Alfalfa and Corn.	5.40	3.74	6.60	3.40	10.00	4.60

and Lot III. ate 33 cents worth more of food per lamb than Lot IV., both being fed corn.

The cost of the food eaten by Lots I. and II. is higher than that eaten by Lots III. and IV., principally because the small grains were more valuable than corn at the time the experiment was carried on. The small grains fed Lots I. and II. were worth $1.00 per hundred pounds, which at that time was 20 cents more than the selling price of corn. The total profit from the eight lambs which were fed wheat, oats and barley was $5.11, while the total profit from the eight lambs fed corn was $9.51.

Attributing all the profit to the alfalfa eaten we find that the average of the small grain fed lot gives a return of $7.58 per ton for the alfalfa consumed, and the corn fed lots gave an average return of $13.03 per ton for the alfalfa consumed. Taking into account the oats in this ration, which are of doubtful value for sheep feeding, and the fact that the lambs were larger than those reported in Experiments I. and II. and were in much better condition at the beginning of the feeding period, the comparative values of the small grains and corn for lamb feeding correspond very closely in all of the experiments reported in this bulletin.

GENERAL SUMMARY.

Beet pulp is a valuable roughage to feed with alfalfa, and we believe would be especially valuable to use during the first part of a feeding period. Pulp fed mutton had good flavor, but was not very fat.

Pulp and alfalfa fed lambs made gains at the least cost per pound, and gave us the largest profit last winter. The second best profit was from lambs which were fed spelt and alfalfa. The third best combination of foods used from the profit standpoint was beets and alfalfa with a ration of grain the last thirty days, decreasing the amount of beets fed at the end of the feeding period. Wheat, barley and alfalfa gave a little better profit than alfalfa, beet pulp and grain. The corn ration gave the least profit when compared with any of the lambs which were fed beets or pulp.

Beet pulp, which does not cost the feeder more than $1.50 per ton at his yards, will give a return sufficiently large to pay for using it in a ration, but we would not recommend letting lambs eat so much of it during the finishing period that they will not consume good rations of hay and grain.

Sugar beets did not prove to have a high feeding value for lambs. It is doubtful if farmers can afford to feed beets to lambs if they can sell them to a factory at $4.50 per ton, and the conditions must be favorable to make beets give a return sufficiently large to pay for raising them. Two pounds of sugar beets were equal to about one pound of pulp.

Sugar beets and poor kinds of roughage cannot be made to take the place of alfalfa hay.

These trials showed that at the same price corn had a feeding value greater than a mixture of wheat, barley and oats, or wheat and barley, or barley alone.

Our single trial with Russian spelt showed it to have a feeding value at least equal to corn, and greater than wheat and barley.

Shropshire grade lambs made much better gains than common western lambs when fed the same ration. Nine Shropshire grades made average gains of 43.6 pounds, and seven native western lambs made an average of 31 pounds.

Our trials with warm and cold water given to fattening lambs did not show any advantage of one over the other.

Bulletin 76. September, 1902.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

Feeding Beet Pulp to Lambs.

—BY—

H. H. GRIFFIN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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Feeding Beet Pulp to Lambs.

By H. H. Griffin.

The establishment of beet sugar factories in Colorado placed the pulp at the command of the farmer for use as stock food after the extraction of sugar. The writer realized that there would be much demand on the part of feeders for reliable information in regard to the value of this product for sheep feeding, as the feeding was done principally for this purpose and probably would be for years to come. The writer further realized that this demand would be emphasized in times of short corn crops in the east and consequent high-priced corn in the Arkansas valley.

It was the wish of the writer to do some experimental feeding with this product in the way of comparing it with corn for fattening sheep. By the kindness of Mr. F. M. Harsin, of Rockyford, 250 head of lambs were placed at our disposal to make a test.

The experiment was planned as follows: One car load of lambs was to be divided into two lots. Each lot was to receive the same amount of alfalfa hay daily. One lot was to be fed corn as it is customary to feed corn in this country. The other lot was to receive pulp in lieu of corn in such amount as would be deemed best for the purpose of making the comparison.

Further, it was intended to incidentally note the effect of the pulp upon the health of the sheep, on the amount of water drank, upon the quality of the meat, and to note how pulp-fed lambs would ship to market as compared to corn-fed lambs. The writer realized that in the latter proposition was, to a great extent, the crucial test of its value.

These lambs were a grade lot from the San Luis valley. Mr. Harsin had put them on hay and corn the first week in November. At the time the Station received them, in December, they were getting 7 oz. of corn per head per day. They were weighed into the Station's pens on the 24th day of December, 1900, 125 in each pen. The weight of pen I was 7,632 pounds or an average of 61 pounds per head; of pen II, 7,772 pounds or an average of 62 pounds per head. Each lot was given the same amount of hay daily. But few of the lambs took to pulp readily. It was ten days before all the lambs in pen II were eating pulp. Pen I was continued on 7 oz. of corn per head daily.

February 21st a stampede of the sheep occurred by which a

few of the corn-fed lambs became mixed with those fed on pulp. They had not been marked, but as those not used to pulp refused to eat it, the separation was easily made.

Both lots were weighed January 3d, and thereafter as often as fortnightly. Pen I weighed 7,710 pounds and pen II 7,744 pounds, so that by the time pen II was eating pulp both lots weighed practically the same.

Pen I was now increased to 9 oz. of corn per head per day. Pen II was consuming 500 pounds of pulp daily, four pounds per head daily, equivalent to 6.4 oz. of dry matter. They were wasting some of this amount of pulp. Both lots were taking practically the same amount of hay, two pounds per head daily. Pen II was held to about 500 pounds of pulp daily until February 2d. At this time the pulp was increased to 750 pounds daily for three days, after which it was increased to 1,000 pounds daily.

It was found that the lambs would not consume this amount of pulp, and that there was also a diminution in the amount of hay eaten. Consequently, in three days the pulp was reduced to about 800 pounds daily, an average of about 6½ pounds per head. The amount fluctuated some because of the waste which occurred. Lot II was continued on this amount of pulp until March 4th.

The corn-fed sheep—pen I—were fed in the same way, gradually increasing the corn, as is the general practice in this section. January 14th they were increased to 11 oz., on February 2d to 13 oz., on March 5th to 16 oz. per head per day. One pound daily per head was the greatest amount because it was difficult to secure corn, and further because the dry matter being fed the pulp lot did not equal in amount that fed the corn lot.

It was apparent that the supply of pulp would be exhausted before the lambs would be in proper condition for market. For this reason it was planned to add corn to the pulp ration and as soon as possible get the corn up to such an amount as the dry matter in the pulp and corn would equal that in the corn lot. Accordingly, on March 5th, the pulp was reduced to 400 pounds daily and 6 oz. of corn added per head daily. The corn lot—pen I—was getting one pound of corn per head daily.

March 27th the corn in the pulp lot—pen II—was increased to 10 oz. of corn daily; the pulp and corn were estimated to contain the same amount of dry matter as the one pound of corn pen I was receiving. Both lots were continued on this ration until the lambs were shipped, on April 16th.

Both lots were weighed at the Station on April 13th. Pen I, which was now reduced to 122 sheep, weighed 10,532 pounds, an average of 86.3 pounds. Pen II (123 sheep) weighed 10,340 pounds, an average of 84 pounds per head.

April 16th the lambs were put on the cars for shipment to

Kansas City. Pen I (121 sheep) then weighed 10,490 pounds, an average of 86.7 pounds per head. Pen II (122 sheep) weighed 10,373 pounds, an average of 85 pounds per head. One sheep from pen II, while being driven to the cars, broke its leg and was not shipped. Four sheep were killed in pen I, two of which were butchered. Pen I thus gained 1.7 pounds per head more than pen II, comparing the weights from January 3d to the close of the feeding.

The weather of December 30th to January 1st was severe, averaging –6° on the 31st, but the gain made by the lambs was fairly good.

TABLE I.

PERIOD.	No. Days.	Hay. Lbs.	Refuse. Lbs.	Corn. Lbs.	Water. Lbs.	Gain. Lbs.
December 24-30	7	1,494	52	351	1,783	
December 31—January 4	5	1,134	86	291	1,575	78
January 5-14	10	2,504	355	708	4,050	279
January 15-24	10	2,250	350	860	4,040	513
January 25—February 2	9	2,125	516	781	3,175	74
February 3-13	11	2,250	325	1,000	3,625	316
February 14-23	10	2,500	270	1,100	4.605	
February 24—March 5	10	2,500	621	1,012⅜	5,360	818
Total	72	16,757	2,575	6,103⅜	29,213	2,078
March 6-27	22	5,588	730	2,750	11,900	652
March 28—April 13	17	4,178	533	2,090	7,200	128
April 14-16	3	680	200	302		44 +
Total	114	27,203	4,038	11,245½	48,313	2,902+

TABLE II.

PERIOD.	No. Days.	Hay.	Refuse	Pulp.	Refuse	Corn.	Water.	Gain.
December 24-30	7	1,527	44	1,780	195		1,275	
December 31—January 4	5	1,134	66	2,325	41		575	-28
January 5-14	10	2:504	379	5,038	92		1,300	216
January 15-24	10	2,250	270	5,020	79		1,675	257
January 25—February 2	9	2,125	268	4,732	22		1,050	131
February 3-12	10	2,250	386	8,671	369		300	276
February 13-23	11	2,500	338	8,969	98		365	
February 24—March 5	10	2,500	661	7,757	102		665	858
Total	72	16,790	2,412	44,292	998		7.205	1.710
March 6-27	22	5,588	870	9,371	46	988	5.075	
March 28-April 16	20	5,607	1,073	6,825		1,607½	3,425	498
Totals	114	27,985	4,355	60,488	1,044	2,595½	15.705	2,678

TABLE III.

DATE.	PEN I.				PEN II.			
	No. Sheep.	Gross Wt. Lbs	Gain. Lbs.	Wt. Per Head.	No. Sheep.	Gross Wt. Lbs.	Gain. Lbs.	Wt Per Head.
December 24	125	7.632		61.0	125	7.772		62.1
January 3	125	7.710	78	61.6	125	7.744	-28	61.9
January 14	125	7.989	279	63 9	125	7,960	216	63.7
January 24	125	8,502	513	68 0	125	8.217	257	65.7
February 2	125	8,576	74	68.6	125	8,348	131	66 7
February 12	125	8.892	316	71.0	125	8.624	276	69.0
March 5	125	9,710	818	77 6	125	9,482	858	75.8
March 27	124	10,362	652	83 5	124	9,952	470	80.2
April 13	122	10,532	170	86.5	123	10,340	388	84.0
April 16	121	10,490	-42	86.6	123-122	10,450-10,373	90	85.0
April 18 (K. C)	120	9,280	-1,210	77 3	117	8.880	-493	75.9

TABLE IV.

Date.	Weather.	Water Drank Pen II—Lbs.	Water Consumed as Pulp, Pen II, lbs	Total Water Consumed, Pen II, lbs	Water Drank Pen I—Lbs.
January 1...	Cold	100	390	490	300
January 15..	Mild	115	441	556	315
February 1..	Cold	100	461	561	300
February 8..	Cool	0	900	900	300
March 1.....	Very Warm	100	750	850	575
March 15....	" "	325	375	700	675
April 1......	Stormy	50	360	410	200
Total......		790	3,677	4,467	2,665

Feeding experiments nearly always show a lack of uniformity in gains, though the weather and kind and amount of food may be constant.

Comparing the gain with the amount of food eaten, the pulp lot compares quite favorably with the corn-fed lot. Were the test to stop here, favorable claims could be made for the pulp. The crucial test came in the shipping. The lambs were forty hours on the way from Rockyford to Kansas City without feed. The shipping showed that the pulp lot were weak-boned and had but little stamina; that the flesh was soft and shrank immensely, giving a much worse appearance than the corn-fed ones.

On the cars four sheep died and one was crippled in the pulp-fed lot; one was crippled in the corn-fed lot. The lambs sold for $4.80 per cwt., the market being from $4.60 to $5.00 that day. The pulp lot in Kansas City had an average weight of 75.8 pounds. The corn lot had an average weight in Kansas City of 77.3 pounds. In shipment the corn lot lost 9.4 pounds per head, and the pulp lot 9.2 pounds. The amount each lot shrank is practically the same. The four dead sheep were, of course, a total loss, which with three crippled (one corn–fed) ones indicates the lack of strength as compared with the other sheep. The attendant stated that the pulp lot sold higher than they would have had not they been on the market in small numbers with corn-fed lambs. Thus while the average weights are about the same, the deaths in pen II and the general appearance of the lot plainly evidenced that they did not ship nearly so well as the corn-fed lot.

The financial account based on the Kansas City returns stands as follows:

117 lambs (fed on pulp), 8,880 lbs., at $4.80..............	$426.24.	Per head, $3.64
120 lambs (fed on corn), 9,280 lbs., at 4.80..............	445.44.	Per head, 3.71
Balance in favor of the corn.........................	19.20.	Per head, .07

If the lambs had been fed pulp exclusively until the time of shipment, I have every reason to believe that the per cent. of loss would have been much greater. Salt was given both lots twice per week, the pulp lot getting one-third more than the others. Evidently lambs fed on pulp should be given plenty of salt because of the absence of bone-forming material in the food.

March 20th one lamb from each lot was sold to local butchers

to test the quality and appearance of the meat. March 28th two more lambs, one from each pen, were sold for the same purpose. Both lots dressed well and the proportion of dressed meat was about the same. The corn-fed flesh was considered some best in color and the carcass showed a good proportion of fat on the outside. The carcass of the pulp-fed lamb showed the most fat on the inside.

The meat from each lot was of good quality and but little, if any, difference could be noted. At the time of loading on the cars one of the pulp lot broke a leg. The lamb was killed and dressed, but it dressed out very poorly. There was but little fat and the meat was of poor quality. This was a typical Navajo sheep, which may account for the failure to put on fat.

As pen II did not become accustomed to pulp until January 3d, the only safe comparison of gains that can be made is for a feeding period of 60 days between January 3d and March 5th.

Referring to table I, we find that for this period pen I ate 5,590 pounds of corn and gained 2,000 pounds. Pen II ate 41,117 pounds of pulp and gained 1,728 pounds. Both lots had eaten practically the same amount of hay. It required 2.79 pounds of corn, in addition to the hay, to make one pound of gain. It required 23.78 pounds of pulp, in addition to the hay, to make one pound of gain. These figures, reduced to their equivalents in dry matter, make 2.37 pounds and 2.34 pounds, respectively. The amount of gain corresponds very closely to the amount of dry matter in the food. Were the pulp so condensed that the same amount of food material could be consumed as of corn, it can fairly be said the results would be equal. These results are based upon the weights at the shipping yards and not at the point to which the lambs were shipped.

Pulp is not a condensed food and the capacity of the animal to take it is limited. The results from the pulp may be partially due to the cooling and regulating effect it may have upon the system. The office of the pulp would seem to be as follows:

On account of its cooling and regulating effect on the system, and bulky, succulent nature, it would be a good thing to feed for some time after taking lambs from the range and putting them on dry hay. For the first two months of feeding the feeder does not care so much for the fat put on the animal as he does for the growth and for the enlargement of the animal's digestive capacity. The alfalfa produces the growth and enough pulp can be consumed to fatten as fast as is desired in the early stages of the feeding.

After the first two months of feeding I believe the lambs should be gradually accustomed to corn, and for the last six weeks of the feeding the pulp should be kept from them entirely.

What, then, is the value of a ton of pulp for feeding to lambs as compared with corn, based upon the results obtained in this feeding trial? The computations so far in this bulletin have been made

upon the supposition that pulp contains 90 per cent. water, which is about right for the pulp we fed. One ton of pulp, therefore, contains 200 pounds of feeding material. For comparison we will consider corn worth, at the cars, 75 cents per cwt. A ton of pulp may be said to be worth $1.50, could it be fed without any outlay for transportation.

The great consideration in estimating the value of the pulp is the matter of transportation. For convenience we will estimate the feeder is such a distance from a factory that it costs him $1.00 per ton to deliver corn to his yards. The corn at above rates costs him, then, 80 cents gross per cwt. It will take practically the same time to deliver a ton of pulp as it does a ton of corn. It has cost, then, to get the pulp $1.00 per ton. This would leave 50 cents for the value of a ton at the factory. If the pulp is shipped then the freight charges must also be deducted to obtain the price which the feeder so situated may afford to pay for the pulp at the factory.

Let us inquire for a moment as to the amount of labor required to transport the same amount of feeding material in pulp as there is contained in ten tons of corn. We will suppose that the feeder is such a distance from the station that he can haul the above amount of corn in 15 hours, or at the rate of one ton in one and one-half hours. The trip can be made with pulp in about the same time, but two and one-half tons of pulp can be hauled at each load because it is of the same bulk as two tons of corn. To haul a ton, which contains 200 pounds of feeding material, the cost then is $1.50. To get a ton of feeding material in the pulp it will take 12 hours; to get the ten tons of feeding matter it will require 120 hours. The cost at 30 cents per hour for man and team will be $4.50 for the delivery of the corn, and $36.00 for the delivery of the pulp.

It may be said that the farmer has the pulp as a by-product of the beet business, and that it will be a waste unless he utilizes it for feed.

Under similar conditions for which the above estimate is made, let us see what it may be considered worth to such a farmer for lamb feeding. The corn will cost him 77 cents per hundred weight (approximately) at the feeding yards. The pulp has cost him only the delivery, or $36.00, which equals 36 cents per ton, or 18 cents per hundred weight dry matter; 77 cents minus 18 cents equals 59 cents, the value per hundred weight of the dry pulp. As there are 200 pounds in each ton, then 59 cents $\times$ 2 cents, or $1.18. From this must be deducted the expense of delivering the pulp (labor of handling), together with the labor necessary to get the pulp from the silo to the sheep – a total of not less than 20 cents per ton. Deduct this from the $1.18 will leave 98 cents per ton as the value that may be attached to it by a farmer so situated.

Mr. Rhodes, of Las Animas, has feeding yards about one mile from the depot. He delivered a considerable amount of pulp to his yards in the fall of 1901. The pulp cost him at the factory 25 cents per ton and the freight was 30 cents per ton, making it cost 55 cents at the railway station. He used a four-horse team and one man to deliver the pulp. He estimates that the total cost delivered at the pen was 75 cents per ton, and when fed from the silo the total cost was 85 cents per ton.

The Station received from the factory 86,410 pounds of pulp, of which 59,576 pounds were eaten by the lambs, leaving 26,834 pounds, or 32 per cent., as the amount of waste or loss. This may be considered as a maximum waste, as we had no silo in which to store the pulp.

Some trouble was experienced in feeding the pulp in very cold weather on account of freezing. At such times it was found necessary to wait until about 9 o'clock in the morning before feeding. Again in the afternoon it was necessary to feed at 3 or 4 o'clock so that the pulp could be eaten without freezing. With large lots of sheep this would be a matter of much consideration.

A record was kept of the amount of water drank by each pen, and is given in table II. The result is interesting, as the question is often asked: "How is it that the animals can consume so much watery material in addition to other food?"

The table shows that, including the water in the pulp, the total amount of water consumed by pen II was greater than that received by pen I. The feeding of pulp is simply one way of furnishing the water supply.

The experience in feeding pulp by different people, 1901, shows that where the animals are confined in pens that the yards become extremely wet. Such conditions are not favorable for the growth of the animal and reduce the benefits derived from the food.

SUMMARY.

Sugar beet pulp contains about 90 per cent. of water, hence there is but 200 pounds of feeding material in a ton.

From weighings made on the sub-station farm the results show about equal gains in weight for the dry matter in the corn and in

the pulp when each are combined with alfalfa.

Hence one ton of pulp is equal to 200 pounds of corn.

Owing to the bulky nature of the pulp not enough of it can be consumed by lambs to produce sufficient fat to finish them; hence it should be fed to the greatest extent at the commencement of feeding.

What is fed in the latter part of the feeding period should be used as an appetizer and a regulator of the bowels rather than for the fat it produces.

Pulp fed in large quantities produces a soft flesh.

The matter of transportation is a very essential one for the farmer to consider in the utilization of pulp. For the profitable use the yards must be near the factory or to railway facilities.

When large quantities of pulp are fed to animals confined in small lots the lots become very foul, much to the discomfort of the animals and loss to the feeder.

Bulletin 77. February, 1903.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

Investigation of the Great Plains.

Unirrigated Lands of Eastern Colorado.

Seven Years' Study.

—BY—

J. E. PAYNE.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

Twelve-foot binder at work near Wray, Colo.

A part of the orchard, and residence at the Plains Substation.

Unirrigated Lands of Eastern Colorado.

Based on a Study and Residence of Seven Years.

By J. E. PAYNE, M. S.

After spending seven years on the Plains, three of which were devoted to traveling and making a special study of the country, and collecting information concerning the results obtained by settlers, we give the statements contained on the following pages to the public.

We are often asked, "Can a man make a living on the Plains?" The only answer which can be safely returned is, "It depends upon the man."

Soil. The soil of the country is quite fertile, as a rule, and whenever it is watered sufficiently at the proper time—either by rainfall or irrigation—abundant harvests are reaped. The most of the soil of the region would be classed as sandy loam. But there are large areas of heavy clay soil, and some which is called "adobe." With some exceptions, the more clay there is in the soil, the more water is needed to raise a crop upon it. Good crops have been raised on some dark sandy soils with very little rainfall. On the "adobe" soil "dry farming" is a failure.

Rainfall. The average rainfall of the country is between fifteen and twenty inches. Records kept for a few years indicate that it is not far from seventeen inches, but they have not been kept long enough to be considered reliable.

Wind. During only a few days in any year is there a dead calm. There is nearly always a breeze, varying in velocity from four to forty miles per hour. At first, this seems hard; but when we consider that nine-tenths of the stock must depend upon water pumped from deep wells, we realize that the wind is an extremely valuable free power, and decide to put strings on our hats and not complain.

Sunshine. Eastern Colorado is eminently a land of sunshine. Very few cloudy days occur. Probably, 300 days in the year are

clear days. If the sun-motor is ever perfected, it will be a great help to this region, for on days when the wind does not blow the sun shines, and the sun-motor would do the work now done by horse-powers and gasoline engines.

Hail. During the eight years we have been at work at Cheyenne Wells, several hailstorms have struck the place. However, no hail sufficiently severe to kill the trees has yet struck there. We doubt that fruit trees and crops generally are destroyed by hail any more frequently there than in irrigated regions of Colorado.

Natural Vegetation. Vegetation grows according to the water supply. Most of the country is covered by short grass. In some places, not more than one-fourth of the ground is covered, while in other places where extra water runs on from surrounding land, the grass makes a complete mat, covering the whole surface. The sand hills and the black sandy land support a variety of tall-growing grasses, which usually grow in bunches, but often grow two to three feet high. The low places often support different species of Agropyron, or Colorado Bluestem — which starts early in the season and matures early in July — making its growth during the season of maximum rainfall. This grass is called "wheat grass" by many, and its habits may be a hint for those who wish to depend upon wheat raising in the plains region. Some do think that if they could get a variety of wheat which would mature by July 4th, it would be practically sure to produce a crop every year. The region between the Arickaree and the North Fork of the Republican River, lying east of the sand hills, appears like a piece of country taken from two hundred miles east of its present location and set down in Eastern Colorado. Along the Black Wolf and Dry Willow are fringes of trees and plum thickets, and wild grapes are quite common there. The rainfall is about the same as in other parts of the Plains.

Water. The water courses of the Plains are mostly sinuous lines of sand of width rudely proportionate to the areas drained. They may carry no water for one or two years, and then a heavy rain may come which changes them to raging torrents. The water does not *run* down their courses; it just tumbles, scooping out great holes here and making immense sand dykes there. If there is enough water, some of it joins some running stream, but as frequently, it tumbles along over the sandy bed until all is used in saturating the upper layers of sand. The surplus caught in the water holes goes into that indefinite, much-dreamed-of body of water called the underflow. Sometimes this underflow of the plains streams follows the course of the present sand-bed, and sometimes it does not. The Plains seem to have an infinite num-

ber of underground streams of varying width. Some are very narrow, and some are so wide that there are regions which are said to be underlaid by "sheet-water." This suggests the possibility of the existence of an underground water system consisting of rills, creeks, rivers and lakes on the Plains. Also, in the same connection, it must be admitted that hills and mountains exist there. If we could strip the country of the soil so as to uncover the shale beds and water bearing sands, it is likely that we would discover a country not so level as now exists there, but with many hills which are now under hollows, and many streams of various sizes trickling through beds of sand much the same as the waters of the Big Sandy pass through its vast sand bed. There are now quite a number of streams in Arapahoe, Washington and Yuma counties whose outlets are covered by sandhills. One of these in Washington county is over two hundred feet wide where the B. & M. railroad crosses it, but it ends on the west side of a big sandhill. The visible streams of water are few. The Big Sandy shows open water at intervals along its course. This stream seems to have an underflow which follows the course of its sand-bed, although it seems to be much wider in places. The Smoky Hill River in Colorado is crossed at intervals by an underground stream which does not follow the course of the present sand-bed any great distance at any place. The South Fork of the Republican is a visible stream for a few miles just east of Flagler, where it runs over a bed of shale. It then goes under the sand, and does not again appear until near Tuttle. From Tuttle to Benkelman, Nebraska, where it joins the North Fork of the Republican, it is a visible stream. The Arickaree River rises near River Bend. It has no known underflow corresponding to its sand-bed until within a few miles of Cope, at the townsite of Arickaree City. Open water appears several miles below Cope, and a small stream is constant in flow between that point and Haigler, Nebraska, where it unites with the North Fork of the Republican. The North Fork of the Republican is a good stream from its source. It is formed by the union of several spring streams in the sand-hills west of Wray.

When the country was occupied by the stockmen, they took possession of the open water, using the range as far out on the flats as their stock could graze from water. They sometimes pushed their cattle out onto the flats when the lagoons were full of water from rains, but as a rule the flats were not used very far from the streams. Those men seem to have seldom thought of pumping water from deep wells for their stock. But, when the country was settled by farmers, they began to dig deep wells. Their necessities caused the introduction of well-augers and well-drills and powerful force-pumps. Windmills were also improved to meet the needs of the times. Soon wells were found in large

numbers on "the flats," which before could be occupied a short time only each year by cattle on account of scarcity of water. Now almost every settler has his own well and windmill, and the grape vines and cherry trees are increasing.

Settlement. The tide of settlers which filled Western Kansas in 1883 to 1885 overflowed into Eastern Colorado in 1886 and 1887. Kiowa and Cheyenne counties were settled thinly; Kit Carson county was nearly all filed upon—especially the eastern half of it; the Idalia and the Vernon divides were settled thickly—all land on the Vernon divide being filed upon, and all as far west as Kirk postoffice on the Idalia divide being occupied. Then, on the west of the sandhills, the country near Thurman, Lindon and Harrisburg was all taken up. All land near lines of railroad—either real or projected—was taken also. Washington county was thickly settled along the B. & M. railroad.

Successes and Failures. The years 1888 and 1889 were quite good years for crops, 1890 was not so good, but 1891 was better, and in 1892 such an immense crop was raised that the settlers called the land "God's country" and wondered why people remained on rented farms in the East when so much free land lay out in this region "only waiting to be tickled by the skill of the husbandman to yield bountiful harvests." Then, people planned large things and went in debt accordingly. Then came the partial failure of 1893, and following this the complete failure of 1894. The year 1895 was much like 1893. In 1893, many left the country. More left in 1894, and in 1895 nearly all who could get away, went. Those who stayed received some help from friends, and worked together to help themselves, and in this way lived through. Each year since 1895, they have raised fair crops. But recognizing the fact that the cows and the hens had saved the country from returning to its old time use as a cattle pasture, the settlers have taken to stock raising, and now the country is upon its proper feet. When the settlers first came in, they attempted to live by grain farming alone. They were taught that grain growing is not the proper basis of successful agriculture on the Plains. They have learned that farming without stock soon impoverishes the man in this country. The country is now resting upon the three legs which are strong enough to sustain it, if used intelligently, through all generations. These are stock, winter forage and summer pasture. It is possible that they may use some cows for dairying when beef cattle prices again go as low as they were in 1889-'94. But the cows are in the country, and they are well distributed now so that no one need leave because he has no cow to tie to.

CROPS GROWN.

Sorghum. Sorghum, including the sweet and non-saccharine varieties, is successfully grown without irrigation everywhere in the region except on adobe soil. The average yield per acre is about one ton, taking a series of years for a test. Only the earliest varieties produce seed. Brown durra, Jerusalem corn, Yellow Milo Maize and some strains of Early Amber cane produce seed; but Red and White Kafir, Early Orange, Colman, Collier and all later varieties of cane and Kafir corn produce very little seed; but these all give good yields of fodder. We find more cane being planted each year we travel. The acreage of sorghum in a neighborhood where crop raising is attempted at all, is a fair index to the status of the cattle raising industry there. In 1900, very little sorghum was planted on the Vernon divide, but in 1902 I saw quite large fields of it.

Millet. This crop is widely grown, and in some neighborhoods is more popular than sorghum. It is not nearly so sure a crop as sorghum, and therefore cannot be depended upon to give a crop every year in all localities. It may be just as sure as sown sorghum, but is not nearly so certain to produce a crop as cultivated sorghum. The average yield of millet will not exceed one-half a ton, and it may not be more than one-fourth of a ton per acre, taking a term of years all over the plains upon which to base an estimate.

Corn. Corn is grown as widely as sorghum, although it is somewhat unpopular in some localities. Over most of the territory a variety is in use which has been developed by the conditions peculiar to the region. It is a low-growing Flint corn. The ears often set on the stalks barely above the surface of the ground. This corn suckers bountifully, so that if the season is a wet one there will be quite a bunch of stalks from the two or three grains planted in one hill. The ears are long, and the cobs large. The grains are so hard that the corn should be either ground or soaked before being fed to horses or cattle. Hogs seem to enjoy grinding the grains, and do well on it, as it seems to be especially rich in protein. This variety, called Mexican corn, is generally grown in the region, except on the Vernon and Idalia divides, where they usually get better results by growing Dent varieties. Outside of the Vernon and Idalia divides, and the black sandy land, the yield of corn is hardly worth mentioning, although some years forty bushels per acre are produced. But the price of grain is usually so high that a very small yield will pay for the work of raising it, and they count upon getting fodder anyway. The average yield of corn on the Vernon divide is probably twenty bushels per acre. On the Idalia divide it will probably average fifteen bushels in a

Grout house of J. Schaal, near Yale, Colorado.
Corrals of J. Schaal, near Yale, Colorado.

series of years. Some years yields are much higher than these figures, and some men may have attained yields averaging much above this for a long term of years, but for the whole district these figures are not far from correct. Some men, single-handed, are cultivating one hundred and fifty acres of corn by the use of improved machinery and a good supply of horses.

Wheat. Wheat growing as a specialty is almost a thing of the past in Eastern Colorado. Men have learned that planting wheat after wheat continuously does not pay. This year we found that wheat following corn yielded about double what wheat following wheat was yielding. This has made corn growing more popular, reduced the acreage of wheat, and has forced people to diversify their crops and engage more and more in general farming, with stock raising as a basis. The yield of wheat on the Vernon divide averages about ten bushels per acre. On the Idalia divide the average is about eight bushels. In the remainder of the territory wheat is so seldom threshed that it would be unfair to publish any estimate, as as high as forty bushels per acre have been harvested, and many years the wheat has been cut for hay when very fair yields might have been obtained. In fact, during the past five years, wheat has been sown more for hay in Kit Carson county than for grain.

Oats. Oats are sown for hay in eastern Kit Carson county, and more or less in all other neighborhoods, except the Vernon and Idalia divides. On the Vernon divide oats average about twenty-five bushels per acre, and on the Idalia divide about twenty bushels.

Barley. This crop is not sown much anywhere in the region studied. The variety raised is one used for feed. Very little is sown outside the Vernon and Idalia divides. There, the yield is usually a little better than the yield of oats.

Rye. Some early varieties of spring rye seem to be gaining favor as a hay crop. There was more rye grown in 1902 than in any other year we have traveled on the plains.

Spelt. This grain is gaining favor also. In July, 1902, I saw a field of fifteen acres of spelt near Vernon.

Trees. Honey locust, black locust and ash are the trees which do the best on the Plains, although elms seem to do quite well if planted among other trees. The hackberry is a native on the Plains, but I have never seen any growing except near streams, or where water was close to the surface. Nearly all the timber claims planted in the early settlement of the country have been abandoned. Just enough trees are alive to show what trees can be

depended upon if given extra care. Upon this subject very little can be added to what was said in Bulletin 59.

Fruit. Of the thousands of orchards planted, only a few trees are alive to show what kind of fruit can be raised in the country. Continued observation has merely confirmed the statements made in Bulletin 59. Gooseberries, native currants, plums and cherries are reasonably sure to produce crops if given especial care. Apples will give crops periodically if not irrigated, and if irrigated are as sure as in other localities. Fruit gardens with facilities for irrigating from wells are growing in numbers year by year.

Irrigation from Wells. As wells are from 80 to 260 feet deep, only very small areas can be profitably irrigated from them. But nearly every settler now tries to have a few square rods of irrigated garden near the well. Some were extremely successful and some were failures; but each succeeding year shows an increase in the number of successful ones. If the sun-motor which is now being worked upon is ever perfected, it may revolutionize the problem of irrigation from deep wells. The main problem will then be to find enough water underground to supply the pumps.

Irrigation from Streams. A few hundred acres are irrigated from each of the main streams. Engineers who have made surveys claim that the flow of the streams is not sufficient to pay for taking the water out onto the flats, and the regular flow is already appropriated for land in the valleys anyway. The fall of the country is so great that ditches two to five miles long would carry the water out onto the flats most anywhere in their courses. If irrigation is ever developed in this region, it must be by catching and holding storm water for use. If a system of low dams for turning the flood water of these streams into reservoirs could be built, beginning at the sources, 5 to 10 per cent. might be irrigated. But this would involve a large outlay of money and labor, and it is to be thought of as a long way in the future. The country is developing along lines of least resistance now, and it is likely to continue in the same way.

Neighborhoods. Kiowa, Cheyenne and Kit Carson county, south of the Rock Island railroad, are quite thinly settled, and stock raising with very little winter feeding is the rule. Only a small quantity of this land has been homesteaded. Settlers live from two to ten miles apart. When claims join, they try to divide the range. Along visible streams and known underground water-courses the land is usually all taken and the stock range over the unoccupied land on each side of the settlement.

Kit Carson county, north of the Rock Island railroad, was quite thickly settled in the eastern half of the county. The settlers who still live there are from one to five miles apart. At Yale postoffice there is a small district which is settled solidly. Crop failures in 1893 and 1894 thinned the settlement. In some neighborhoods, the depopulation was made permanent by uncertain water supply. The settlers now in Kit Carson county have settled down to stock raising with farming as a side issue. There are still a few men who say that they cannot afford to raise feed for their cattle any more than enough to carry them through the storms.

Arapahoe county on the Idalia divide as far west as Kirk postoffice was all filed upon. Settlement thinned in 1893-95 on account of crop failures, but people are still too close together to keep their cattle at home during the summer. It is the custom to send the cattle to the thinly settled districts for pasture. On this divide wells are plentiful, but they are from 100 to 260 feet deep.

The Vernon divide lost much of its population in 1894 and 1895, but has regained it since. Practically all of the land on this divide is in private hands, and unimproved land is selling at $1,000 per quarter section. Except upon a small area of about twelve square miles south and southeast of Vernon, wells are sure on this divide. Water is found at from 90 to 100 feet.

Lindon and Harrisburg lost all population except a few families. Within the last two years some good wells have been found in the neighborhood, and a few ranchmen have quite a number of cattle in the neighborhood now.

Near Akron and Yuma, and along the B. & M. railroad, where nearly all the land was once filed upon, settlers are from two to eight miles apart now. But there is a tendency for new settlers to crowd in there again.

THE LIVE STOCK INDUSTRY.

From the nature of the conditions the live stock industry must always be the main business on the plains. The problem before those who would use the country is: How much stock can be kept on a specified area?

The methods of handling stock are changing gradually from the range system with no feed, to feeding with winter shelter. As the ranges become more crowded, more feed is used during winter. Evidence now seems to show that much of the country will at some time be used as a summer range only, and the cattle will be fed during the winter in adjoining districts where crops of forage are raised.

There is a growing feeling among the wealthier cattlemen that it pays best to use their ranges for the summer only, and bu

young stock in the spring to be sold in the fall. Others are taking up the idea of producing forage on a large scale so that they can feed all stock whenever it is necessary. Still others count upon moving all cattle to where there is plenty of feed and hiring them wintered. It is noted that farmers on the Vernon divide now often take cattle to winter. But the greatest number of cattle will undoubtedly be raised by men who own bunches of from twenty-five to one hundred and care for them by the work of themselves and their families. These people can make a living by milking a few cows when cattle are low in price, and then they can turn the milk more towards beef making when cattle are high.

My travels on "the divide" south of Denver gave me some idea of the possibilities of the dairy business on the plains. Some of the settlers on the plains are now using hand separators and shipping their cream. This simplifies dairying and leaves the skim milk at home for the calves, and at the same time it materially lessens the labor connected with dairying.

Poultry. Some people have made quite a success in raising poultry. The sunshine of the plains, when combined with proper feed and care, makes the laying hen extremely popular. The production of winter eggs, combined with winter dairying, has proved extremely profitable on a small scale in a great many cases. One woman who kept accounts showed me a record of 100 hens for a year. The eggs had given a profit of one dollar per hen for the year, and she had raised 190 chicks besides. Another woman raises several hundred chicks every year, using incubators and brooders. She buys the eggs for hatching from her neighbors as she keeps no roosters. All young roosters are sold when they reach broiler size. The pullets are kept for the production of winter eggs. She raises mostly Leghorns. Of course, there have been many failures in the poultry business on the plains also—failures too numerous to record. Those who succeeded in the poultry were very careful hands, and they have made a thorough study of the business from the beginning.

GENERAL OBSERVATIONS.

Since beginning the investigations, the country has been constantly improving. The houses built of sod from sandy loam soil do not usually stand much more than fifteen years, while those made of adobe soil last indefinitely. However, the sod roofs soon become leaky and need frequent replacing. We find many sod roofs replaced by shingle roofs, and it is rare that the old sod house is replaced by a new sod house nowadays. In nearly all cases wooden houses have taken the place of the "soddies" when they became uninhabitable. When first traveling over the country in 1900, we found very few who were intending to stay in the coun-

try. Each year we have traveled, we have found more people who were improving their places and deciding to stay and make real homes for themselves. The result is that permanent improvements are taking the places of temporary makeshifts which were put up to last until the owners could get away. And now, not so many places have the "I want to sell out" appearance once so characteristic of nearly all.

Near Vernon and Wray, the farmers are becoming comfortably fixed. Many of them are connected with each other by telephones. Once last summer while staying over night at one of the farms an orchestra was called up and all on the line enjoyed a very entertaining concert. This may surprise some who think of the whole country as but little better than a desert.

CULTURE.

The practice of the most successful farmers is to plant all crops which are cultivated during growth with a lister. The harrow is often used in cultivating until the plants are so large that it would break them if used. Gang weed cutters are used by many for cultivating listed corn after it is too large to be cultivated with a harrow. The ordinary shovel cultivator is used for the last cultivation. Some are listing their ground east and west in the fall and listing again in the spring. The fall listing is done in order to catch the winter moisture. The method of culture which is most successful is the one by which a soil mulch is maintained throughout the growing season so as to prevents excessive evaporation. Very few men prepare ground for wheat with turning plows. The cultivators and disk harrows have been found more satisfactory in preparing ground for wheat. One man claims good gains in yield by listing his ground east and west in the fall and discing in the spring. Sorghum is sometimes sown, but is much surer to produce a crop if it is planted with a lister and cultivated. It has been found that much of the winter moisture can be saved for the crop by discing the land in March. Sometimes this will save a crop. Wheat following corn is now giving the best returns in wheat seed. Wheat sown between March 1st and March 15th seems to give the better average yields than later or earlier sowing.

CONCLUSIONS.

1. The country is improving rapidly.

2. The sod house is disappearing. In a few years "soddies" are likely to be rare, except on newly settled places.

3. When prices of cattle are low, the "dual-purpose" cow is likely to become prominent, and creameries and cheese factories will receive support from the owners of small herds.

4. The production of winter eggs should be a good business on the plains.

5. If the country continues to settle up, in a short time all stock must be fed and sheltered during winter.

6. The stock industry is in a transition stage. Unless methods change, a herd of more than 300 cattle owned by one person will soon be rare.

7. Sorghum is rapidly gaining ground as a forage crop, because it is one of the surest crops known where droughts are common.

8. The number of acres it takes to sustain a cow is estimated at from ten to thirty. With a large area of carefully selected land in drought resistant forage crops the number of animals which could be kept in the country could be increased considerably.

9. The Vernon and Idalia divides, especially the Vernon divide, must be considered as farming districts. These communities raise grain for sale practically every year, and they can be depended upon for supplies of winter feed for cattle which graze in the thinly settled neighborhoods in the summer. Many farmers near Vernon now take cattle to winter, and the evidence indicates an increase in this business in the future.

10. In all districts except the Vernon divide and some parts of the Idalia divide, it will probably pay best to confine the farming to raising rough feed for wintering stock.

11. Stock raising must be the basis of all successful agricultural efforts in this region, and crop raising should be generally attempted as an aid to stock raising.

12. Each home can have a few trees, which can be kept in good condition by using the waste water.

13. Some men will fail on the Plains; but we must consider that success or failure everywhere depends upon the man behind the business.

Bulletin 78. February, 1903.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

THE TOMATO INDUSTRY OF THE ARKANSAS VALLEY.

—BY—

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PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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THE TOMATO INDUSTRY IN THE ARKANSAS VALLEY.

BY H. H. GRIFFIN.

There are five factories in the valley devoted almost exclusively to canning the tomato. A successful pack for them means a considerable revenue to the farmers. The production of this crop has not been attended with uniform success. To get the best results has been a perplexing question, both to the farmers and to the factory operators. Poor success with this crop cannot be ascribed to diseases or insect pests, for neither caused any serious loss.

One complaint has been that the vines would grow large but fail to set fruit in sufficient quantity. Another, and more prevalent one, was that the vines would be well filled with fruit but too late to mature before injurious frosts. Most of the time the result has been that the major portion of the growers were disappointed in the returns from the crop, and the factories have been without a sufficient supply to operate profitably.

The writer was of the opinion that the troubles of the tomato growers were not entirely due to difficulties of soil or climate, but rather to the lack of a well defined system of propagation and cultivation.

To throw some light on this subject a systematic study of this crop was begun and the results of three years work are embodied in this bulletin.

The tomato is a native of tropical America where it was cultivated by the natives before the continent was discovered. For many years it was cultivated in this country and in Europe as an ornamental plant. It was considered poisonous, and went by the name of "Love Apple." It began to be used for food in some places about the beginning of the last century, but as late as 1832 it was considered a curiosity in New England. The value of the crop in the United States is now several millions of dollars annually. Tomatoes are now put on the

market in many forms and are considered an indispensible article of diet. About 300,000 acres are devoted to the growth of this crop in the United States, and the pack averages about 5,500,000 cases.

Productiveness of the tomato in the northern states, is largely a question of early bearing;—this is especially true at our altitude, where the season is comparatively short. The plant will outlive the seasons of the north, hence its life is determined by the contingencies of frost rather than by any inherent limit of duration. It does not mature at our altitude and it would probably continue to bear for some months if not frosted. It is apparent that all advantage possible must be taken of that portion of the season most favorable for its fruiting. That the lack of success in the Arkansas valley is not altogether a matter of seasonal difficulties is evident when we compare results with those in northern Colorado, one thousand feet higher, where the canneries are uniformly successful. In some parts of this district the yield averaged fourteen tons per acre in 1901. The product was so large that the canneries were unable to handle the acreage contracted.

I have ample reason to believe that aridity is an important factor in determining the yield of this crop. And another factor, no doubt, is the prevalence of strong winds or dashing rains at the period when the plant is blooming profusely.

Dropping of the bloom is quite a familiar occurrence. Often whole clusters drop, leaving not a single flower to produce fruit. As the tomato is a native of a warm, moist climate, it is apparent that dry, windy conditions, followed by cold nights, are not favorable to the pollenization of the flower and the setting of the fruit. For this reason every possible advantage must be taken of the growing season, so that if the bloom fails to set at one period there will be ample time to secure good results later. This principle is often well illustrated with the cantaloupe; a crop which there can be no doubt is adapted to this section. Cold, windy conditions may prevent the pollenization of the flowers for a short period and the result is that the fruit fails to set. This will be noticeable during the growing period. The yield is lessened thereby, and is especially noticeable if the plants are rather late ones so that the shortage may not be made up by later favorable conditions. It is reasonable to assume that the same condition holds true with the tomato.

It is common practice to plant the tomato on impoverished land or on land quite sandy, where it would not be expected to get good returns from most other crops. The opinion seems to be wide spread that a well enriched soil is positively detrimental to the tomato.

Tomatoes yielding six tons per acre will take from the soil 25 lbs. of potash, 18 lbs. of nitrogen and 8 lbs. of phosphoric acid. The vines will require 34 lbs., 28 lbs. and 4 lbs. respectively. A crop of tomatoes removes twice as much potash and over fifty per cent. more nitrogen than either a crop of Irish or sweet potatoes. Thus we see that the tomato, contrary to opinion, is a gross feeder. It may appear as composed mostly of water but there is an immense seed production that demands con siderable fertility.

Prof. Bailey, of New York, after experimenting with fertilizers for this crop a number of years has the following to say:

"It is a common belief that the tomato, unlike most plants, is not benefitted by rich soil or heavy manuring. Our tests give uniformly heavier yields in heavily fertilized land. There is some reason for the widespread belief to the contrary. Much may depend upon the soil and still more upon the character of the fertilizer. It should be one quickly available to the plant. Fertilizers that give up their substance late in the season give poor results because they delay fruitfulness.

Prof. Earle, of Alabama, says there are but few soils in that state rich enough to grow satisfactory crops of tomatoes without fertilization. The following conclusions are drawn from careful experiments in New Jersey.

"That nitrogen is an important element in growing tomatoes. With sand, the increase in the use of nitrate is nearly five times that with minerals only. That a full supply of nitrogen is more effective on a sandy than on a clay soil."

Growers of tomatoes in Mississippi use on fairly good land, 400 lbs. of cotton seed meal, 400 lbs. of acid phosphate and 100 lbs. of Kainit per acre.

All of the above places have conditions naturally more congenial to the tomato than are our conditions. The season is much longer, the nights warmer and yet we see how essential they consider it to push the plant forward.

EXPERIMENTS IN 1900.

The Perfection and the Stone were the varieties used in the trials. The seed was put in the hot-beds about the first of April, intending to have the plants ready to set in the open field about the 10th of May. It was not the intention to do any transplanting. The soil

was as nearly uniform in quality as possible to get. For two years the greater portion of it had been fallow, the remainder in bluegrass. No fertilizer was used.

May 8th, two rows, (one of each variety,) 140 feet long were planted to the seed in open field. May 9th and 10th ten rows, (five of each variety) were set with plants from the hotbed. They were to receive treatment as follows: One row to be pruned while the plants were small; one after the plants were well advanced. The plants in another row were to be transplanted after growing sometime in the field. Two rows were to be grown according to usual practice as a check upon the results. The plants used in this work were of medium size, taken from the original bed; the kind of plants that are commonly set in this valley. May 28th, one row of each variety, was set with the same class of plants for a comparison of late planting.

We thus had the following questions under consideration:

1. Plants started in the open field compared with plants set from the hotbed.
2. The effect of early trimming.
3. The effect of late trimming.
4. The effect of transplanting after growing for a time in the field—whether or not it would retard growth and hasten ripening.
5. Plants set late in May compared with those set early in the month.

The early pruning was done June 19th, 28th and July 9th. The late pruning was done August 9th and consisted of a shortening in of the side shoots and tops of the vines.

The Perfection gave the first ripe fruit August 9th, from one of the check rows. The first ripe fruit was taken from the Stone and from the check row August 24th.

The plants of the Perfection, set in field May 28th, did not ripen fruit until September 3rd. The other plantings, except seed in the field, were yielding considerable fruit by the first of September.

The following table gives the yield per hill of each row:

	Perfection. Lbs. per hill.	Stone. Lbs. per hill.
Seed in field	2.6	1.5
Early pruning	3.9	3.1
Late pruning	4.4	3.3
Field transplanting	4.7	3.2
Late setting	3.0	1.4
Check row	4.2	2.7

A yield of six tons per acre is represented by about 4.5 lbs. per hill.

The Stone did not bear much until the first week in September. All of the plantings were then yielding ripe fruit except that made May 28th, which did not bear until September 18th.

It should be noticed how uniform was the yield from all the plantings made early in May. The plants set late in May yielded about the same and commenced to bear about the same time as the plants grown from seed.

I had under observation one field in which considerable pruning had been done, but there was no benefit derived.

The work of the season was intended to be largely of a preliminary nature, the press of other work not enabling us to take up the question extensively. It should be noticed that the work was to test whether those ideas popularly held were true, i. e.—that the plants grew too much to vine at the expense of fruit.

From the results of the year it was quite evident to me that a lessening of the vine was of no benefit. It was also evident that late set plants were of but little value.

SEASON OF 1901.

The work of this year was along different lines from those of the preceding year.

It embraced two distinct lines. 1. Experimenting along certain lines at the station. 2. Observations, among the growers, of the methods employed and the success obtained.

The work of the station was planned as follows: (*a*) A comparison of different classes of plants, also a comparison of the time of setting in open field as affecting maturity and production. This included the use of transplanted plants (very stocky,) set early in open field. Also plants, not transplanted, set in open field early and late, and plants produced from seed sown in open field. (*b*) The yield and maturity of plants compared when grown on land heavily manured, (barnyard manure well rotted,) with land having no fertilizer. (*c*) Variety tests. The work was badly handicapped by a hail storm on the 24th day of July. For a time it seemed as though the results for the season would be destroyed. Owing to the effects of the storm, only general results can be given, but the facts are sufficiently clear to warrant the conclusions, verified as they are by the results of others.

The seed of a Beauty tomato was sown in hotbed March 2nd, and plants from this sowing transplanted to

another bed April 13th. Seed was again put in hotbed the last of March to get plants for later setting.

April 19th, a planting of seed was made in open field. Irrigation was at once employed to germinate the seed and the plants were showing by the 30th of the month. It is not often safe to have plants in open field as early as this. This planting was made on land well enriched with barnyard manure.

April 24th, twenty very early plants were set in open field on the same land as above. They were large, lengthy plants, what might be called "leggy." May 7th and 8th a considerable planting was made of plants from the hotbed. It consisted of transplanted plants (strong and stocky,) set on heavily manured land. The same kind of plants were also set on land having no fertilizer. Untransplanted plants were also set on both the fertilized and unfertilized land. Thus on the manured land were four classes of plants. May 3rd, a planting of seed was made on unfertilized land.

May 8th, on unfertilized land, some very small plants (smaller than those above mentioned) were set, and on the 16th of May, still another planting was made. About one acre of land was used in these trials.

By June 15th the bloom was plentiful and small tomatoes had formed on the transplanted plants growing on the manured land. By the middle of June all of the plants on the manured land were blooming well, but those on unfertilized land contained but few blossoms. The first fruit was picked July 16th from the transplanted plants growing on the manured land.

At the time of the hail, July 24th, all of the plants, except those set May 16th, and those grown from seed planted May 3rd, had set some fruit. Much the best set being on the transplanted vines on manured land.

The first ripe fruit from the plants grown from seed on manured land was picked July 29th. This was about two weeks later than from transplanted plants. It was August 23rd before any ripe fruit was taken from the plants set the 16th of May, more than a month later than the first ripening. The last of August the plants on the manured land were yielding fully twice as much fruit as those on unfertilized land. The early plants were yielding much better than the late ones.

It was the middle of September before fruit in any quantity was taken from the plants grown from seed planted May 3rd, or from the planting of May 16th. Just

what effect the hail may have had upon the various dates of ripening cannot be told. The total yield of perfect fruit was light. It was the intention to have a record of each planting, but it was found it would reveal nothing owing to the injury of so much fruit by hail.

Close observation was kept of some tomato fields, especially of such as were apt to give some data along the lines we were studying.

March 3rd, Mr. J. H. Crowley put tomato seed in hotbed and transplanted to boxes in another bed April 2nd. These boxes were made of building paper by cutting the desired size, folding and tying with a string. The boxes were left on the plants when they were put in the field. The plants were set in open field May 14th, at which time they were more than a foot in height and blooming some. Part of them were put on land that had been fertilized with nine loads of sheep manure per acre. The other portion was put on the same kind of soil but having no fertilizer. The first ripe fruit was taken from the vines on manured land July 4th, about three weeks earlier than the others. Mr. Crowley estimates the yield from the manured land as being about 60 per cent. the greater. Wherever the manure was applied there was an immense benefit, apparent in the size of the vine and the amount of fruit.

Messrs. Fullmer and Sanders had about four acres of tomatoes on alfalfa sod. They made their first planting in open field about May 10th. Some of the plants were potted but the greater portion were from the original bed. The first ripe fruit was taken July 8th, from the potted plants.

The last week in May another portion of the field was set with plants from the original bed. From this planting the first ripe fruit was picked the first week in September. There was a difference of only three weeks in the time of putting the plants in the field, yet there was seven weeks difference in the period of ripening. The early planting yielded heavily and by the first of October was still yielding as well as the later planting. Thus we see the tomato will bear a long time if the ertility is present to support the plant.

From the field about 40 tons of fruit was sold, 34 tons going to the cannery. It was estimated that the yield from the first setting was 12 tons per acre, and from the late setting 8 tons per acre.

The last picking was made October 20th, at which

time there were immense quantities of green fruit on the plants set late in May. If frost had come as early as usual these plants would not have made the returns they did. This is quite a striking example of the benefit to be derived from the use of strong, early plants. This was the finest field of tomatoes I had yet seen in the valley. If it were true that a heavy nitrogenous fertilizing would produce vine at the expense of fruit, we would expect to see such results in this instance. On the contrary, we find this field yielding double, and often treble, what many other fields did in the vicinity.

Another striking example of the benefit derived from the use of manure was on the farm of Mr. Foster, Manzanola. His land is quite sandy, consequently it gets very hot during the summer. Part of his tomato land had been manured quite heavily. The same class of plants were used throughout and the planting was done at the same time. The plants on the manured land grew large and thrifty and made a good yield. Those on unfertilized land were small, unthrifty and many blighted. The yield was not sufficient to warrant the labor expended.

SEASON OF 1902.

This was largely a continuation of the work of 1901. However, more time was given to observing the work of different growers, especially in the vicinity of Manzanola. Mr. Barton, of the Manzanola Canning Co., was much interested in the effort to improve the industry and extended many courtesies.

The work on the station land comprised the following:

1. Comparison of plants grown in the field with those from the hotbed.
2. Comparing transplanted plants with those not transplanted.
3. Comparison of land well fertilized with land not fertilized.
4. Comparison of early and late plants.

April 26th, seed was sown in open field on land heavily manured with rotted barnyard manure. Speedy germination was secured. Adjoining these were set, on May 7th, thirty-five long spindling plants taken from the original bed. They were from a bed made early in March. Adjoining these were set, on the same date, seventy plants taken from the same bed but which had been transplanted a short time. There was but little difference in the appearance of the plants from the two sources. The plants were purchased for the purpose of making the comparison. Next to the above were set transplanted plants that were of nice size, strong and stocky. They

were from a bed made early in March and transplanted to another bed about the middle of April. Some plants of medium size, considered of medium quality, were taken from the original bed and set at the same time (on manured land) as those above mentioned. The latter class of plants were also put on adjoining land that had not been fertilized. The plantings to this time comprised 27,160 square feet of land.

May 14th, we set in open field some small transplanted plants together with some from the original bed. These were small plants but as good as many that are used every year by those growing for canneries. May 26th, another planting was made with plants from the original bed. These plantings were made on land that had received no fertilizer for years and comprised six-tenths of an acre.

After the setting of the plants, irrigation was given two or three times until the plants were well established, after which they were thoroughly cultivated and hoed. The next irrigation was June 18th. It was again irrigated commencing July 15th, and the water was last applied the 20th of August.

The first ripe fruit was taken July 25th from the stocky transplanted vines set on the 7th of May. In a few days the purchased plants and the larger ones from the original bed were also ripening fruit.

August 10th, 13 lbs. of ripe fruit were picked from the former vines, on the 20th, 54 lbs. were picked and on the 22nd, 137 lbs. From this time this class of plants were yielding in such quantity as to warrant picking and delivering to a canning factory. The plants put in the field May 14th were not setting fruit until the last week of July, at about the same time the transplanted plants on manured land were ripening fruit.

The first to ripen of the May 14th planting was the transplanted vines, August 25th. The plants put out May 26th did not ripen fruit until the first week of September.

August 25th a few ripe tomatoes were taken from the plants grown from seed (planting of April 26th.) As in 1901, plants grown in this way ripened their fruit about the same time and yielded about the same as late plants from the hotbed. If the season is favorable and the conditions are such as to push the plant, ripe fruit can be secured in time to get fair returns. The fruit picked from the vines set on May 7th amounted to 7,487 lbs. or, at the rate of about six tons per acre. The greater portion was picked

before frost became severe enough to seriously injure the fruit. The yield would have been larger had the seed been true to name. It was purchased for the Beauty but the product resembled the Acme more.

The equal area set May 14th, yielded only 2,550 lbs., or, at the rate of 4,250 lbs. per acre. The difference in the yield of the two plats can be attributed to the difference in fertility, the class of plants used and the time at which they were set. It can be attributed mostly to the first two causes, as there was a difference of only one week in the planting, but nearly a month in the time of ripening. The greater portion of the yield was secured after severe frost and the fruit was more or less injured. The results are in harmony with those secured by other growers.

A factory with a considerable acreage, similar to the early ones, could begin to pack by the 20th of August. September would be well advanced before packing could commence if the acreage corresponded to the last can. The tonnage would not be sufficient nor the quality satisfactory. The grower becomes discouraged and is slow to again venture in the business, preferring to put his land to some crop in which the returns are greater and surer.

THE FIELD OPERATIONS.

It is difficult to draw conclusions from this work for the reason that in but few cases can comparisons be drawn. The class of plants used, the kind of soil, the time of setting, attention given, and fertilizer used, seldom enable any comparisons to be drawn. Hence it is difficult to get very much reliable information from a vast amount of this kind of work. One little experiment where the conditions are under control is apt to be worth much more than the observation of many conditions of which we know but little.

Probably the best crop of tomatoes grown in the valley this year was that of Mr. H. W. Harlow, near Manzanola. From 1¼ acres he took 18 tons of tomatoes. The soil on which the crop was grown had supported cottonwood trees until two years previous. The location was in a swale, the soil naturally quite rich and enriched by the addition of much vegetable matter from the tree leaves, etc. The land was fall plowed dry, turning up in large prices. The planting was done about the middle of May with plants from the original bed, the plants were of good size, thrifty and forced from the start. Mr. Har-

low states that he replanted some missing hills in June but at picking time could discern no difference. This, I think can be accounted for from the fact that the vines were extremely large, very closely planted together and difficult to tell one plant from another. The rows were four feet apart and the plants 3½ feet in the row. One plant occupied about 14 square feet of land, hence an acre contained about one-third more plants than are ordinarily grown. The fruit was a very fine specimen of Beauty, which augmented the yield. A portion of the plants were from seed saved by Mr. Harlow. The vines were so large and so thickly covered the land that the first frosts did them but little injury, in fact, rather aided the ripening. The first delivery to the factory was made August 27th, but the heaviest yield was from October 11th to 23rd. Thus it is seen that the field was not an early one, which could not be expected from the class of plants used. The conditions in this field are such that no comparisons can be drawn, but it is of interest by reason of results secured.

The field that gave the most promise early in the season was one of about 14 acres, most of which was alfalfa sod. Many of the plants used were grown as follows: The seed was put in hotbed the middle of February and transplanted to a muslin covered bed with under heat (manure) in March. The tops were clipped to make the plants stocky. They were set in open field about May 10th; strong and stocky with a splendid root system. Some of the plants from the original bed were also put on the alfalfa sod. These were also good plants with good root systems. On some cultivated land near by some of the late plants were set; small, weak plants compared with the others. Owing to the scarcity of water, this field could not get the desired attention. It was in an exposed location and a severe wind about July 20th, did it much damage. At this time all of the plants on the alfalfa sod were large and thrifty and appeared to be well set with fruit. The late plants were small and no fruit had set. On August 16th I took particular note of the amount of fruit on the transplanted vines and those not transplanted, both on alfalfa sod. It was estimated the former were supporting nearly twice as much fruit as the latter. Ripe tomatoes were picked from this field August 1st. About the 16th of the month from 150 to 200 lbs. was being picked every other day. Delivery to a factory could have commenced by August 20th. As heavy

returns were being made to the factory during the last week of September, as at any time during the season. It was one of a few fields to make its heaviest returns prior to October 1st.

This field suffered for water the whole season, but especially during the latter part of July when water was demanded the most. It can be truly said that the scarcity of water was responsible for the light yield which this field gave. The late set plants gave no returns. The comparison that could be made here showed the superiority of the transplanted plants.

Another field, to which particular attention was given, was one of about three acres on very sandy land. About two-thirds of it had been manured with unrotted sheep manure. The plants were from the original bed and of fair size, set in open field about May 20th. There was a portion of the field set about two weeks later than the above. About July 20th the early plants on the manured land had considerable fruit of good size and it was still setting. The plants set later were much smaller and were just commencing to form the fruit. By the last week in August the vines on the manured land were large and thrifty, well set with fruit. They had been yielding some ripe fruit for nearly a month. Delivery to the factory was made at the time of opening, August 25th. The yield was 30,194 lbs. besides much shipped to market. The heaviest deliveries were made about September 20th. The vines on the unfertilized land gave much the lighter yield and were about three weeks later ripening. Water was used in abundance but this was made necessary by so much dry heating material in the soil. As an instance of what early planting and good plants will do, we record the following: The above grower had a few good plants set in the garden in April and protected for a time from frosts and winds. These plants ripened fruit July 20th and bore well for the season.

Special mention might be made of many fields but it will suffice to give a general account of results. In nearly every instance when small plants were set rather late in open field, and especially on land given no special preparation, fruit formation did not commence until about July 20th. From observation made this season it is found that the time required to ripen the fruit after formation is from forty to fifty days. This was true of the first fruit that formed. If the forming of the fruit is delayed until the 20th of July there will be none ripe before the first of

September and the greater portion of it will not ripen until about October 1st. It can be readily seen what an advantage there is in having the fruit ripening by the last of July. It means that the heaviest deliveries can be made about the middle of September, before frost does serious injury to the tomato, thus insuring a good uniform pack with much less loss than in the late one.

After the middle of September, the nights begin to get quite cool and usually the tomato ripens slowly.

The results as a whole indicate that soil conditions play considerable part in tomato growing. The tomato seems to prefer a virgin soil, and a sandy soil is preferable to a clay. Considerable adobe is not desirable.

Increase in vigor and productiveness evidently are closely associated with careful handling and good tillage. There can be no question that transplanting, properly done is invaluable. *Stocky plants*, vigorous and growing well *are better* than simply early plants. This was plainly shown in our tests of 1902. On the other hand, transplanting does not avail anything over early plants well grown unless the transplanting is done a sufficient time to increase the root system of the plant, together with its strength and general vigor.

Good healthy plants started medium early and kept growing vigorously are preferable to early plants allowed to get too thick in the bed, which causes them to become spindling and stunted in their growth. They are also preferable to a transplanted plant that has been stunted. A good tomato plant, at time of setting in the field, is one which is stocky enough to hold the weight of itself, together with a considerable amount of dirt, about the diameter of a lead pencil and 6 to 8 inches in height. A tall, weak plant is not worth setting. The desirable thing to secure in this country of short seasons and cool nights is a plant having age. It stands to reason that the older the plant the sooner it will commence to bear—it takes about so long for a plant to come to the bearing age. The most successful way to accomplish this is by transplanting. If this is not done care should be exercised that the plants do not become crowded and "leggy" before time of setting.

We must bear in mind that the tomato will not give profitable returns without more care in the selection of seed, plants and soil than is given most of our staple crops. Special preparation must be made for the crop. A small acreage grown under the most favorable conditions is

worth more than many times the same amount put in and tended in a haphazard way.

VARIETIES.

During the season of 1901 the writer had under trial or observation with different growers the following varieties: Magnus, Success, Burpee's Combination, Enormous, New Large Early, Fordhook First, Fordhook Fancy, Quarter Century, Acme, Tall Queen, Ruby, Dwarf Champion, Kansas Standard, Perfection, Matchless, Truckers' Favorite and Beauty. Of this list there are but few that seem to have any merit for this country. For canning purposes, where it is necessary to combine earliness, appearance, quality and productiveness, the Beauty easily takes the lead. The factories recommend this variety. It is also a splendid shipper. The Acme is a little earlier and for early shipping to markets may be preferred to the Beauty. The Fordhook First is also a good early shipper. During the past season there was much loss occasioned by the failure of plants to bear fruit typical of the Beauty. It was a great disappointment to have the yield so materially reduced and it was a source of loss both to canner and grower. Seed selection has never been given proper attention by the growers and it is one reason why success is not oftener obtained. The tomato is one of the most variable and inconstant of garden plants. Authorities say that varieties of tomatoes as a rule are short lived and that ten years may be considered the profitable life of a variety. Many of us are aware that old standard sorts are now extinct.

To illustrate this I wish to quote from Bulletin 32, Bailey & Lodeman, (October 1891) of the New York Experiment station, under the heading of "Do varieties of tomatoes run out," it has the following:

"For some years it has been apparent to the writer that varieties of tomatoes run out or lose their distinguishing characters. The reasons for this loss of varietal character are not necessary now to discuss. Crossing, no doubt hastens it in many cases. But it is well to state that running out does not mean deterioration simply, but disappearance of characters by whatever cause. Studies of this question were made this year by growing the same variety from many seedmen. This gave us an opportunity to determine if the variety had varied greatly in the course of its history, or if all seedmen really sold the same thing under a given name. In order to determine how long a variety may persist, we selected Grant and Canada Victor, which are old varieties; and to find how soon a variety may depart from its type we grew the Ignotum."

"Grant was obtained from seven seedsmen,—all who catalogued it. Of these seven samples, but two were true Grant as the variety was recognized years ago. The remaining five samples grew fruits

of various kinds, although somewhat resembling the Grant type. It may be said that these variations were due simply to mixing of the seeds during a number of years by careless handling, but there is reason to suppose such is not the case. The Grant has a peculiar small, slightly curled, light colored foliage and a well marked upward habit of growth of the young shoots. These characters appeared constantly in all the samples. The foliage, being less variable than the fruit and not an object of selection by the horticulturist, had remained constant, while the fruit had lost its character."

"Canada Victor was grown from ten seedsmen. There were none which could be recognized as true Canada Victor, but they were all small, variable, irregular and practically worthless. Yet in all the samples, the peculiar, slightly curled foliage of the Canada Victor was apparent."

"Ignotum was obtained from fifteen dealers. This variety was first offered by seedsmen in 1890. Of the fifteen samples, eight gave small and poor fruits, which were not worth growing and could not be recognized as Ignotum by any character. The other samples were fairly uniform and represented a medium type of Ignotum.

"Ignotum grown from one of our own savings gave a number of plants which bore inferior fruits, although clearly Ignotum. It is difficult to suppose that in one season a variety could so far have lost its characters that one-half the seedsmen should offer inferior stock of it. The variety is well fixed, for in one of our large plantations of it, it was remarkably uniform and equally as good if not even better than two years ago."

DISTANCE TO PLANT.

The vines should be sufficiently close to shade the ground during a portion of July and August. The heat and reflection of the sun from our light colored soils often have an injurious effect upon the tomato plant. On well fertilized land I would recommend that the plants be set about 4 feet each way. That it is none too close we have good evidence in the field of Mr. Harlow, previously noted. His plants were even closer than this and yet he got more fruit on one acre than many secured on four acres.

The sun and heat evidently cause physiological troubles, which growers often include under name of blight. A familiar trouble of this kind is a blackened condition of the plant, or portion of it, late in the season. This is quite prevalent on light, sandy soils where the plants are small and exposed.

The trouble first manifests itself on the south-west side of the plant. I have never seen it when the plants were large and covered the ground. The plants have been examined for fungi and bactria by competent persons but none have been found present. It seems to be physiological trouble caused by excessive heat. Blistering of the fruit is quite a common occurrence when it is exposed and is often a source of considerable loss. It

well illustrates what a powerful effect the sun has upon exposed vegetation.

Another disease is sometimes present which is commonly termed blight. It has been described as caused by bacteria and very much resembles the field or southern tomato blight. It first manifests itself by the top leaves folding together and turning yellow. It gradually destroys the leaves downward, the first affected leaves dying. Finally the stem turns yellow and the plant slowly succumbs. Exposure to the reflection of the sun's rays from light colored soils seems to favor its development. This was well illustrated in 1901, where a grower had trained about one dozen vines to stakes and kept them pruned up high according to the practice in the southern states. Every one of these plants were destroyed by this disease and much of the fruit that formed was blistered. By the side of these plants about one-eighth of an acre of tomatoes were set out at the same time but which had grown sufficiently rank to cover the ground. There was no sign of the disease on these plants, the fruit was not injured and the yield was good. This disease was reported by the writer in New Mexico bulletin No. 21. It was found there that the disease was much worse on the light sandy soils than on the dark colored bottom lands.

The fruit of the tomato is occasionly affected by what is commonly termed blossom end rot. This is a blackened condition of the blossom end which gradually enlarges until the tomato is destroyed. There is no efficient remedy known. It is possible that a too free use of irrigation water late in the season may increase it.

IRRIGATION.

The tomato does not require an abundance of water but it requires a constant and uniform supply. The most water should be applied when the fruit is forming, when the vines are in bloom quite well. As soon as the plants have become established, only sufficient water should be given to keep them growing nicely. This is the time the cultivator and hoe are demanded. The growth of the tomato is of a succulent nature and should not be forced too much by a plentiful supply of water in its early stages. The result of so doing will be a tender growth of a yellowish color instead of a healthy green, forming wood instead of fruit buds. If the water is withheld until the bloom is well started, a plentiful supply will aid the setting and growth of the fruit. However, it should not be

applied too late, as after the nights become cool watering may retard the ripening.

In the Holbrook country this season were some good illustrations of the drouth resisting power of the tomato. The last of August I saw large thrifty vines that had been watered but twice, once at the time of putting in the field and again the first week in August. Where the best results were secured the land was very retentive of moisture, as was also the subsoil, which furnished a small but constant supply. Some of these fields gave promise of ripe fruit by early September, yet tomatoes were not marketed in quantity until about October 20th.

INSECTS.

There are two common insects which trouble this crop every year, viz: the tomato worm, (*Protoparce celeus*) and the corn or boll worm, (*Heliothis armigera.*) The former is very easily controlled by spraying, yet it is surprising how few growers utilize any means of this kind, but will put in much time destroying the worm by hand. Any of the poisons as commonly used for spraying apple trees will be effective against this worm. The best material to use is the arsenate of lead for it will not injure foliage, no matter in what strength used.

The latter is the larva of a night flying moth. There is no very successful way known of controlling this insect. It is sometimes recommended to plant sweet corn near the tomatoes as a trap crop. We tried this remedy this year with considerable success. It can be said that those growing near the corn were nearly free from worms, while those at a distance were injured to a considerable extent. Three successive plantings of corn should be made, the first at the time the tomatoes are set. Each planting should be disposed of before the worms get large enough to leave the ears. The Hazeltine moth trap was tried during the season of 1901 to note if the extent of injury could be reduced by this means. The trap was set two or three nights in a week and the catch sent to Prof. Gillette for determination. We failed to catch a corn worm moth during the season.

THE SAVING OF SEED.

A few instances have come under my observation where splendid success was obtained from the use of home grown seed. The fruit was large and typical of the

variety. A portion of the crop grown by Mr. Harlow was from seed of his own saving. Too often purchased seed is not what it is recommended; it may be (for all the purchaser is aware) the refuse from canning factories. It would seem the wise thing for our growers to save their seed from perfect specimens.

PROPAGATION OF THE PLANTS.

Every grower of tomatoes should be prepared to grow his own plants and these of the finest quality. By so doing he has the plants at hand to put in the field, without any deterioration in quality, when the soil is ready and the water at hand. To get the best results, the soil for the bed should be prepared by composting. It is not essential that glass should be used, but it is preferable for starting early plants. Canvass requires considerable more care and labor in affording additional protection. Furthermore, it requires considerable more bottom heat as there is not so much heat secured from the sun. In times of bad weather too much shade may be the result with canvass, causing the plants to grow too spindling.

When plants are started in February or early March, glass should be used. Before they become large enough to crowd (in early April) they may be shifted to a canvass covered bed.

CONCLUSIONS.

1. Some good crops have been grown every year and if proper methods are employed good results may be secured by a large majority of the growers every year.
2. Seed of known quality must be used.
3. Proper selection of varieties is essential.
4. The plants must be started early so as to give them age, strength and a good root system.
5. The plants should be thrifty and set in open field as early as frost will permit.
6. Sandy or loamy soil is preferable but it should be well fertilized with some quick acting fertilizer; that a virgin soil and alfalfa sod give good results.
7. A constant and uniform supply of moisture, but not too abundant until the blooming period is well started.
8. Close planting that the ground may be shaded to avoid injury to vine and fruit.
9. The tomato is a valuable crop with which to subdue alfalfa for succeeding crops.
10. The crop should be ready for canning fully three weeks earlier than has been the custom, thus insuring profit to the grower and the packer.

Bulletin 79. March, 1903.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

TREATMENT OF STINKING SMUT IN WHEAT.

—BY—

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PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

TREATMENT OF STINKING SMUT IN WHEAT.

BY JOSEPH REED. *

INTRODUCTION.

It is not the purpose of this paper to present anything new in the way of preventing smut in wheat. Many remedies have been tried, some of them giving very good results, others giving poor results, and in some cases the germinating power of the grain was destroyed. While the practice of treating seed wheat for the prevention of stinking smut is quite general in many localities, yet from the many inquiries that come to the Experiment Station in regard to smutted wheat it is evident that the treatment is not understood by all. Some growers try a good remedy but fail to obtain good results because they neglect an important detail. Others treat their seed one year with good results while the next year the same treatment may prove a failure. Such an experience is likely to discourage further effort to combat the disease. But it is safe to say that failure is always due to the remedy being improperly made or applied. The evident good results the first year may have been due to a small amount of diseased seed rather than to the treatment. The second year the disease was still unchecked by the inefficient remedy, and increased enough to cause considerable loss.

A small amount of smut in grain cannot be readily detected. Many people conclude, therefore, that their seed is free from disease and so dispense with the treatment. Many times a crop can be grown without treatment, but on the other hand a better crop might have been produced from treated seed. At any rate the farmer who treats his seed is not running any risk; he has a cheap insurance.

Before starting these experiments all available literature on the treatment of wheat for the prevention of smut

* A Senior Student in the Agricultural College. The experiments were carried on with the advice and under the direction of Professor Paddock.

was consulted. It was found that a great number of remedies have been tried, but it was hard to decide which was best. The object then in view was to obtain the best remedy that was cheap and easy to use. Many experiments have been performed with the hot water treatment. This is a good remedy but it is inconvenient to use; the water must be at just such a temperature, if below 130 F, it will not kill the smut, if above 140 F, it destroys the germinating power of the grain. Taking into account the heating of the water, the cost of this treatment is about as great as other remedies which give good results and which are much easier to use.

Smut seems to be worse some years than others. Some experimenters say that this is because of the amount of moisture in the soil, some years being so dry that all the smut spores cannot germinate. Varying amounts of moisture probably have an influence on the disease, but since the spores germinate with the grain the smut will most likely germinate if the grain does. It is of the authors' belief that variation in the amount of smut depends more upon the seed that is used. Many farmers after growing wheat free from smut a few years think it is useless to treat and consequently stop, or if they do treat, the operation is carried out very carelessly; this neglect is what gives the smut a chance, so allowing the disease to be more plentiful some years than others.

Occasional reports come to the Department from all over Colorado that smut has destroyed a whole crop of wheat, and numerous cases where the crop is badly affected. To the unobserving person this grain looks as well as any, while it is in the shock, but when the threshing time comes a large part of the supposed grain is blown on the straw pile in the form of smut spores, some of the spores lodge on the grain, and some pass out as whole kernels in which the outside covering has not been broken and is hauled off with the grain.

STINKING SMUT OF WHEAT.

(*Tilletia foeteis.*)

Stinking smut is a fungus which destroys the kernel of the wheat. This disease lives over winter in the form of spores which are microscopic in size, black in color, and globular in form. The interior of the kernel is frequently completely filled with a mass of these spores and when the outer coating is broken, as is often the case, the spores are set free and many of them lodge on the healthy grains and are held by the minute hairs which occur on the kernels at the end opposite the point of attachment.

The spores can live through very unfavorable conditions and they germinate under the same conditions as the wheat. The smut spores begin their attack as soon as the wheat grains have sprouted. The germ tubes enter the young wheat plant where they appropriate nourishment for the development of the smut plants. From this time on the two plants grow up together, the smut growing in the interior of the wheat stalk.

When the wheat stalk heads out and the kernels begin to form, the smut attacks them and absorbs the nutritive substance from the kernel. The smut then forms its seed-like spores which live over winter, and are produced only in the interior of the kernels, the glumes surrounding the kernel being unharmed. This is why smutted grain often looks healthy and well developed, but sometimes these glumes surrounding the kernel break away at the top and spread out, thus giving the head of wheat a ragged appearance. It may not be noticed that the grain contains smut until the shell of the kernel is broken and the smut spores are set free. Diseased kernels can usually be told, however, in that they are somewhat swollen and darker in color. It is known that one smutted kernel contains many thousand spores. When the grain is threshed the spores are scattered all through the grain and a crop that has but little smut one year may be nearly all smut the next year. Some grain with smut spores may fall on the ground and come up the second year as volunteer grain; this is the reason why we have smut when clean seed is planted if the same ground is seeded to wheat.

There are two kinds of smut, the Stinking Smut and Loose Smut. The Loose Smut obtains its name from the

loose-like condition which the smut is in after the spores are formed. In the loose smut the whole head of wheat is attacked, the glumes and all parts of the head are turned into a mass of smut spores which are often blown away by the wind before the grain is cut.

There are two species of Stinking Smut—*Tilletia foetens* which has the smooth spores, and *Tilletia tritici* which has spores with net-like ridges on the outer surface of the spore wall. The Stinking Smut obtains its name from its disagreeable odor, a small amount of it in the grain spoiling the flour.

THE EXTENT OF INJURY.

Stinking Smut causes more injury than is generally supposed. It has been known ever since the time of the early Greeks, but it has only been within the last ten years that very much work has been done to find a preventative. Investigations made at other Experiment Stations show that the loss may be from 1 per cent to 75 per cent of the crop. This loss is not altogether the loss of the grain, but what grain is saved can only be ground up for feed, for if it contains 15 per cent of smut it is unfit for flour. W. T. Swingle says: "There are no accurate statistics as to the amount of damage caused by these smuts. In many localities the loss is very large, and it cannot be doubted that in the whole United States it amounts to many million dollars annually."

By treating the seed every year this loss may be prevented. Smut will not appear unless the spores are planted, except what occurs on the volunteer grain, which is already in the field, caused by successive planting to wheat.

If a crop does not contain smut one year it is not a sign that the same wheat sown on the same ground will not be diseased the next year, because spores may be brought to the seed wheat by the threshing machine, or be carried by the wind and lodged on the grain. The only safe rule is to treat all seed every year. It is possible to grow a crop for several years without having smut, but in localities where it is common or where it has been and is partially stamped out, the seed should be treated every year.

METHOD OF TREATMENT.

Two methods of treatment were used in the experiment, soaking and sprinkling. The grain that was sprinkled was spread on a floor and the solution sprinkled on. The grain was shoveled over and over until all the kernels were

wet, care being taken that no more of the solution was added than was required to wet every kernel. In the soaking method the grain was placed in a tub, then the solution was added until the grain was completely covered. The mixture was stirred so every kernel came in contact with the solution and all floating kernels were removed. The grain was soaked different lengths of time, as shown in the table on page 5.

CHARACTER OF GRAIN AND SOIL.

In order to give the treatment a thorough test the worst smutted grain that could be found was used. It was so badly smutted that it had been sold for hog feed and no one would think of planting it to raise a crop of wheat. When the grain was placed in the tub to be soaked the solution was colored black by the smut spores.

The soil upon which the grain was planted raised a crop of oats the year before, and previous to that time it was used for a nursery. The soil was in very good condition to raise grain, and it certainly did not contain any smut spores.

The ground was divided into ten plats of equal size, the first and last plats were used as checks, being planted with untreated grain. All plats were seeded broadcast.

TREATMENT OF GRAIN AND RESULTS.

No. of Plats.	Treatment.	Method.	Strength of Solution.	Time.	ercent smutted Heads.
I.	Untreated				80 %
II.	Copper sulphate	Sprinkled	1 lb. to 4 gals		½ %
III.	Corrosive sublimate	Soaked	1 lb. to 50 gals	10 min	½ %
IV.	Corrosive sublimate	Sprinkled	1 lb. to 50 gals		½ %
V.	Copper sulphate	Soaked	1 lb. to 4 gals	2 min	2 %
VI.	Formalin	Sprinkled	1 lb. to 45 gals		nearly free
VII.	Potassium sulphide	Sprinkled	1 lb. to 8 gals		75 %
VIII.	Copper sulphate	Soaked	1 lb. to 24 gals	12 hrs.	5 %
IX.	Slaked lime	Mixed	1.4 lbs. to 20 lbs		50 %
X.	Untreated				80 %

DETAILS OF EXPERIMENTS AND DISCUSSION OF RESULTS.

The grain was treated March 14, 1902. When the treatment was over, all the grain excepting that treated with slaked lime, was spread out on the floor to dry. The lime and the wheat were well mixed and then placed in a conical shaped pile until planted. Three persons carefully estimated the percent of smut in the various plats.

Plat No. 1. Was planted with untreated seed. This showed that the seed was extremely smutty as eighty per cent. of the heads were diseased.

Plat No. II, planted with grain sprinkled with copper sulphate in proportion of one pound copper sulphate to four gallons of water; this gave the solution a dark blue color. One-half of one per cent. was the result. This result is much better than could be expected from the seed used.

Plat No. III. Planted with grain soaked ten minutes in a solution of corrosive sublimate in the proportion of one pound to fifty gallons of water. This gave one-half of one per cent. of the grain diseased.

Plat No. IV. Planted with grain sprinkled with corrosive sublimate in the proportion of one pound to fifty gallons of water, this gave the results of one-half of one per cent. of the grain diseased. These results prove that sprinkling is as good a method of treating as soaking.

Plat No. V. Planted with grain soaked two minutes in a solution of copper sulphate, in proportion of one pound copper sulphate to four gallons of water, giving results of one-half of one per cent. of the grain diseased.

Plat No. VI. Planted with grain sprinkled with a solution of formalin in proportion of one pound formalin to forty-five gallons of water. Scarcely a smutted head could be found in the plat. This result not only shows that formalin is a good remedy, but it also shows that the sprinkling method can be depended upon.

Plat No. VII. Planted with grain sprinkled with a solution of potassium sulphide in proportion of one pound to eight gallons of water. This gave very poor results, seventy-five per cent. smut. The solution was probably a little weak, but the result obtained shows that it could hardly be made strong enough to be a complete prevention.

Plat No. VIII. Grain soaked 12 hours in a weak solution of copper sulphate, one pound to twenty-four gallons of water. Result five per cent. of diseased wheat.

Plat No. IX. Planted with grain mixed with slaked lime in proportion of one-fourth pound lime to twenty pounds of grain, this gave poor results, fifty per cent. smut. With the use of any more lime the grain could not be sown evenly.

Plat No. X. Planted with untreated grain, the results of eighty per cent. of the grain diseased.

SUMMARY.

I. The results obtained in these experiments are remarkable because the seed used was so badly diseased. No one would think of using such grain for seed. With ordinary seed the treatments that gave the best results, would insure a crop entirely free from smut.

II. The sprinkling method proves to be as effective as the soaking method.

III. Copper sulphate, corrosive sublimate and formalin prove to be efficient remedies.

IV. Copper sulphate in a weak solution will not do good work even when allowed to soak a long time, twelve hours for instance.

V. Potassium sulphide is a very poor remedy for smut besides being expensive.

VI. Sprinkling with copper sulphate is recommended to be the best remedy. Solution, one pound of copper sulphate to four gallons of water. It is the cheapest, the handiest to use and gives as good results as any treatment tried.

VII. The smut is planted with the grain and germinates at the same time. If the seed is free from smut then the crop will be unless volunteer grain comes up in the field.

VIII. To treat the grain by the sprinkling method, place the grain in a bin large enough so the grain can be shoveled from one side to the other. Sprinkle the solution on with a common watering pot and at the same time keep shoveling the grain over and over. When the kernels are all wet the treatment is finished, but great pains must be taken to see that the work is thoroughly done.

IX. Because the grain is clean one year do not run the risk of its being free from smut the next, but treat every year.

X. The grain should not be treated very long before it is planted because it will start growing. After treatment it should be allowed free circulation of air so that it will dry quickly.

XI. The sprinkling method is by far the quickest and easiest method. If the user does not have a floor to spread the grain out while treating, a canvass, or any large cloth can be used.

Bulletin 80. March, 1903.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

Laying Down of Peach Trees.

—BY—

WENDELL PADDOCK.

PUBLISHED BY THE EXPERIMENT STATION.
Fort Collins, Colorado.
1903.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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Laying Down of Peach Trees.

By WENDELL PADDOCK.

Peach growing, from a commercial standpoint in Colorado, is largely confined to the western slope of the mountains. The trees find a congenial home in many localities in several counties, consequently large areas are devoted to the cultivation of this fruit. Peaches have been extensively tested in various fruit sections east of the mountains, and in the Arkansas Valley in particular an occasional fine crop is produced. Indeed some of the best exhibits at the State Fair last fall, were grown in this section. But in four years out of five, perhaps, late spring frosts or extreme cold in winter destroy the buds. North of the Valley, peaches are rarely produced unless the trees are protected in some manner.

This experience, when success was just within reach, stimulated the growers in their efforts to overcome climatic conditions. Various devices were tried for protecting the trees during the winter and spring. These included wrapping the trees with cloth or covering with corn stalks, evergreen boughs, boards and, in fact, most anything that was at hand that might afford protection, but after several years trial, these methods were found to be of little use. In the fall of 1896, Hon. W. B. Felton, of Canon City, began experimenting with laying trees down, using two trees in this first trial. Mr. Felton was closely followed in this work by Mr. C. C. Rickard, also of Canon City, and to these two men belong the credit of working out this system of protecting trees in Colorado. And, in fact, after a rather hasty consultation of horticultural literature, I do not find any record of this method of protecting trees having been tried at an earlier date.

From this modest beginning an industry has sprung that is now assuming no mean proportions in that vicinity. A large number of fruit growers have planted peach trees varying from a few to several hundred in number. Mr. Rickard is, perhaps, still the largest grower, having now 1,000 trees in bearing.

The method of planting an orchard with the intention of laying the trees down during the winter, does not differ materially from that which is ordinarily observed. Some, however, claim that when the tree is planted the roots should be spread out on

Fig. 1. Three-year-old tree in full bloom.

Fig. 2. Mr. C. C. Rickard in his ten-year-old orchard.

either side of the tree at right angles to the direction in which it is to be laid down. Mr. Rickard pays no attention to placing the roots, claiming that in a few years the roots spread so that any evidence of training is lost. Others make a point of setting the trees close enough in the row so that when laid down the tops of one tree shall overlap the base of another. The roots are thus afforded protection as well as the tops.

The following data furnished by Mr. Rickard is given in detail as it represents the experience, not only of the largest grower, but of one who has had the longest experience in this method of growing peaches. As is true with many horticultural operations, there are different ways of doing the same thing, consequently other growers differ with these instructions in points of minor detail, but in general, the process must be the same.

Yearling trees are set in the spring and they should be laid down the first winter, repeating the process each season during the life of the tree. In this instance no attention is given to training or placing the roots. As soon as the trees have shed their leaves and the wood is well ripened, they are ready for winter quarters. This is usually in the fore part of November, in the vicinity of Canon City. The first step in the operation consists in removing the earth from a circle about four feet in diameter around the tree. When sufficient trees have been treated in this manner to make the work progress advantageously, water is turned into the hollows. After the ground has become saturated the trees are worked back and forth and the water follows the roots, loosening the soil around them so that they are pushed over in the direction that offers the least resistance. When treated in this manner the trees go over easily and with comparatively little injury to the root system. That is, providing the trees have been laid down each year. It is difficult to handle old trees in this manner that have never been laid down, and usually it will not pay to try.

After the trees are on the ground, further work should be delayed until the ground has dried sufficiently to admit of ease in walking, and in the handling of the dirt. The limbs may now be brought together with a cord, and so lessen the work of covering.

After experimenting with many kinds of coverings, burlap held in place with earth has proved the most satisfactory. The burlap is spread out over the prostrate tree top, as shown in the photographs, taking special pains to protect the blossom buds from coming in direct contact with the earth covering. A light layer of earth is now thrown over the tree and the protection is complete.

The critical time in growing peaches by this method is in the spring when growing weather begins. Close watch must be kept

to see that the blossoms do not open prematurely, or that the branch buds are not forced into tender, white growth. When the blossom buds begin to open, the covering should be loosened so as to admit light and air, but it should not all be removed. More of the covering should be removed as the weather gets warmer, but the blossoms must be exposed to the sun gradually.

Air and light are, of course, necessary for proper fertilization of the flowers, but after this process is complete and the fruit is set, all danger from the weather is considered as being over. The trees are usually raised about the middle of May at Canon City.

Raising the trees is, of course, a simple task. The ground is again watered and when wet enough the trees are raised. To be sure, trees that have been treated in this manner will not usually stand upright unsupported. Consequently they are propped up at an angle, usually two props being required to keep the wind from swaying them.

When this method of growing peaches was first presented before the State Horticultural Society by Senator Felton, it was received with not a little sarcasm by some of the members, but the practicability of laying down trees is now no longer questioned. The constantly increasing acreage of peaches at Canon City proves that it pays. The actual expense is, of course, difficult to estimate, because of the attention required in the spring. The cost of the fall work can be estimated, however, as it has been found that two men will lay down and cover twenty-five of the largest trees in a day.

This process seems to be in no way detrimental to the health of the trees, since they live as long and bear as much fruit according to the size of the top as those grown in peach sections. It is, of course, necessary to cut out the wide spreading branches and thus reduce the size of the top in order to lessen the work of covering.

The following is the record of yields as given by Mr. Rickard: In 1902, 150 ten-year-old trees and 350 nine-year-old trees produced fifteen tons of fruit, or at the rate of 60 pounds per tree. In 1901 the yield was almost the same, but in 1900, 20 tons, or 80 pounds of fruit per tree was secured.

The marketing of peaches grown on this farm has thus far been a simple matter, as most of the fruit is sold at the orchard, and at prices ranging from 3 cents a pound for culls to 10 cents for fancy stock, the average price being 6 cents a pound. So long as the fruit can be sold in this way the expense of packages is reduced to a minimum.

But how about growing peaches in this manner north of the Arkansas Valley? Can it be done? Most assuredly it can, and it is done every year, but only in a small way, and the trees are so few and in such widely separated neighborhoods that they attract

Appearance of same row on April 25 and on September 20.
Orchard of J. J. Lewis, Canon City.

little attention. The most successful attempt of which I know has been made at Berthoud, a town 50 miles north of Denver, by M. H. Warfle. Mr. Warfle's experience is summed up in the following paragraph:

I have thirty peach trees. In 1901, the second year after planting, I had about twenty-five boxes of fruit. In 1902, fifty boxes, and the outlook is good for a big crop this year. The varieties I grow are Alexander, Triumph, Mountain Rose, Bakara No. 3 and Elberta. Any good variety will do well if they are laid down.

These few pages are written not with the idea of presenting anything new, but to draw attention to the fact that peaches can be grown with a certain amount of profit in most of our fruit growing regions. But the pleasure to be derived from a home supply of this luscious fruit should not be underestimated. The peaches grown at Canon City always command a higher price on the home market because they are of better quality when allowed to ripen on the tree. Those that are shipped in must be picked before fully ripe in order to stand transportation.

In many parts of the state the price of peaches is so great that many families are compelled to do without. But by using this method of laying down the trees, as worked out by the pioneer truit growers of Canon City, the small land holder can provide his family with peaches of much better quality than can be bought on the market, and with little expense.

Bulletin 81. **March, 1903.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

Onion Growing
In the Cache a la Poudre Valley.

—BY—

WENDELL PADDOCK.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

Plate I. Three hundred and twenty sacks per acre.

Onion Growing in the Cache a la Poudre Valley.

By WENDELL PADDOCK.

Colorado is remarkable for its special crops which have been developed to a high degree of perfection in certain localities. And of these, few have attracted more attention than onion growing in the Cache a la Poudre valley. As early as 1880 a few gardeners in the vicinity of Laporte, began to grow more onions than were required to meet the local demand. Much of the surplus was hauled by wagon to Cheyenne, Wyoming, or it was disposed of to ranchmen, and in small towns where there was no local supply. At this time onions brought from $1.75 to $1.90 per hundred pounds. Commission men from Greeley were not slow to recognize in this crop a valuable means of supplementing the sale of potatoes. These men soon became the principal buyers. With the advent of the commission men, the acreage devoted to this crop increased rapidly, until now onions are grown in varying amounts on the bottom lands adjacent to the river from the foot hills to its junction with the Platte at Greeley, a distance of forty miles; the territory adjacent to Fort Collins still continuing to grow the largest acreage.

While the price of onions has been reduced to a minimum, 65c to 75c per hundred pounds being the average price in the fall, yet the crop is usually a paying one. Owners of small tracts of land find it profitable to put in small patches of the best soil, and perhaps the larger part of the onions is grown in this way. But occasionally a twenty-five-acre field is seen, and ten-acre fields of onions are not at all uncommon.

Soils. The onion thrives best in a cool, moist soil, the surface of which is easily kept in a mellow condition. Such soils are mostly confined to river bottoms, and they contain more vegetable matter and more sand than is commonly found in Colorado soils. Large amounts of decayed vegetable matter seem to be essential to the best development of this crop. Many of the best onion districts in the East, as well as in California, are located on reclaimed swamp land. One very important effect of the vegetable matter is that it improves the physical condition of the soil,

and if this is combined with a certain amount of sand a loam is formed that is easily made into the proverbial onion bed.

Heavier soils are not suitable for onion growing, for the following reasons: It is difficult to make a good seed bed, free from lumps. The seeds do not germinate quickly and the young plants are fragile, consequently much damage is done if the ground bakes or cracks, as it is liable to do, before the plants come up. Germination may be seriously interfered with, or the young plants killed or injured so that their development is checked. Such soils are difficult to cultivate, especially when the plants are small, and after irrigation is begun the tendency to bake is greatly augmented. The percentage of scallions, or thick-necked onions, is much greater on such soils.

The onion plant is a surface feeder, consequently it must have an abundant supply of readily available plant food in the surface soil. If the ground is compact the roots cannot nourish the plant properly, even though plant food is abundant. Then, too, the bulb must be free to expand naturally on the surface of the ground, which it can only do when the soil is loose. If the soil is compact, development is arrested and the onions are small and many scallions are formed. Many onions are grown on soils that are heavier than is desirable, but special care is taken in irrigation and cultivation.

Preparation of Land. In preparing land for onion growing, the growers are divided in their opinions and practice in regard to spring and fall plowing. Perhaps the majority plow in the spring or late winter. Fall plowing has advantages for certain soils, as it tends to kill out weeds, such as wild oats, and if the ground is inclined to be lumpy the action of frost tends to reduce the lumps and thus much time and labor is saved.

After the ground is plowed it must be harrowed and gone over with a clod crusher until it is in a fine state of tilth. Ground as ordinarily prepared for wheat will not do for onions. After the soil has been thoroughly prepared the surface must be leveled so that there will be no possibility of water standing on any portion of the field.

Fertilizing. Rotation is not usually practiced, the same land being planted to onions for several years in succession. Comparatively large amounts of manure are required to keep up the fertility of the soil under these conditions. The practice of some growers is to apply from 30 to 40 tons of sheep or horse manure per acre once in two years, while others make a similar application every three years. Of the two kinds, sheep manure is preferred. Commercial fertilizers have probably not been tried in this valley.

Plate II. Single row system of planting.

Seeding. Seeding is begun as early as March 15, and is continued as late as April 20, though it is desirable that all seed be in the ground by the 10th of April. The importance of early seeding should be emphasized, as it is essential that the bulbs make as much growth as possible before the hot weather of midsummer comes on. The seed is sown about one inch deep, with hand seed drills, using from three and one half to four pounds of seed per acre. The distance between the rows depends on the system of irrigation to be followed. If the field is to be flooded the rows are usually made 12 or 14 inches apart (Plate II). But if the furrow system of irrigation is adopted, the ground is plowed out in ridges after it has been thoroughly prepared. The ridges are made 30 inches apart and then flattened to about nine inches on top. Two rows, three inches apart, are planted on each ridge; the furrows between the double rows being used for irrigation and for cultivation (Plate III). Most growers try to plant the seed so that the plants will be one and one half inches apart in the row, so as to avoid thinning. In fact, but little thinning is done in this vicinity.

Cultivation. Cultivation and weeding is begun by hand as soon as the plants appear above ground. Cultivation is given with a hand wheel hoe, while weeding and thinning, if thinning is necessary, must be done by hand. The number of hand weedings that are necessary will depend on the season, but usually three are sufficient. The ground should be cultivated after each weeding, and at such other times as the season indicates. Four or five cultivations are required in the vicinity of Fort Collins.

It is important that weeding be attended to promptly, lest the plants become weak and spindling from the crowding of the weeds. Many plants may be killed during the process of weeding, and others may soon dry out and die as a result of being suddenly exposed to the sun.

Irrigation. Specific directions for irrigating onion fields cannot be given, since methods must necessarily differ in different fields and in different seasons. In the first place, damp, but not wet soils, are selected, when possible. Such a soil does not need much water in the fore part of the season, and when of the proper texture the fields may be flooded, when water must be applied without damaging the crop by subsequent baking of the surface. In the vicinity of Fort Collins irrigation is not begun before the first of July, and is continued at intervals of ten days or two weeks, according to the conditions of the season. Further down the river, where heavier soils are used, the ground is irrigated by running the water in furrows between double rows, as mentioned above. In this case irrigation is started the same day that the

seed is planted, if the ground is dry, or as soon after as possible. Subsequent irrigation will depend on weather conditions, but close attention must be given to see that the ground is kept moist. On the other hand, too much water must not be applied, as it results in the formation of scallions and of spongy bulbs.

Harvesting. Onion harvest is commonly begun by the 15th of September, and the crop is usually out of the field by the middle of October. Harvesting should begin promptly when the bulbs are mature, as is indicated by the withering of the tops and the yellowing of the necks.

The onions are pulled by hand and thrown into windrows, where they are allowed to remain for several days to cure. After the curing process is complete the bulbs are topped, sorted and sacked. Topping is done by cutting off the tops about half an inch above the bulb, care being taken to make a smooth, clean cut, and not to injure the outer coverings. If more top is left on it detracts from the appearance, and if cut closer the bulb is liable to be injured.

The onions are now sorted and sacked in the field, making but one grade. The small and unmarketable bulbs, together with the scallions, are left on the ground. Gunny sacks which hold about 100 pounds are the only packages used.

Ordinarily damage by rain is not feared after the onions are sacked, but if they do become wet they should be left in the field until dry. The sacks should be turned as soon as the tops are dry in order that the bottom of the sacks may have an equal chance to dry out. This is especially true if the ground is wet.

The growers do not usually attempt to hold their crop, but haul it directly to the car or to the dealer's warehouse. All onions should be out of the field by the first of November.

Markets. The principal market for Colorado onions is in Texas, though some are sent to Oklahoma and Indian Territory, and occasionally they are sent as far east as Kansas City and St. Louis. A portion of the crop is disposed of by the dealers soon after it is delivered by the growers, but perhaps two thirds of it is held until February. Onions that are held any length of time in storage must be resorted before they are placed on the market.

Varieties. A great many varieties of onions have been tested by the growers in this district, but none have been found that meets all requirements as well as the Yellow Globe Danvers. It is practically the only variety grown. A few Red Danvers are grown, but the amount is scarcely worthy of mention. The Yellow Globe seems to be well adapted to our conditions of soil, altitude and climate; it yields well, keeps well, and its size and appearance meet the demands of the market.

Plate III. Double row system of planting.

Several years ago Mr. A. T. Gilkison, of Laporte, experimented with transplanting Prizetaker onions, as is extensively practiced in other states. The onions yielded well but the bulbs did not keep well, and were larger than the market demands. Judging from this experience, the so-called new onion culture is not adapted to our conditions.

Seed. Too much attention cannot be given to procuring good seed. If the seed is old, its germinating powers may be lost or impaired, and if close attention is not given to selecting the best bulbs for seed, the stock deteriorates rapidly. Poor seed may be accountable for a poor stand, many small and immature bulbs, or a large per cent. of scallions. Onions grown from seed as commonly supplied from seedsmen, are so greatly influenced by our conditions of altitude and climate that the growers soon began to raise their own seed. The larger part of the seed now sown in in this valley is home grown.

Cost of Growing. Onion growers differ in regard to the cost of producing this crop. Of seven growers consulted, one estimated the expense at $90 an acre; another at $50. The other five gave figures varying between these extremes. It is probable that on an average $60 will cover all the expense, excepting the cost of manuring, from plowing the land to loading the onions on the cars.

Storing. It has been found that onions keep better in rooms above ground than in cellars. Such rooms should be open so as to admit of a free circulation of air until there is danger of freezing. When severe weather comes on a stove should be placed in the room if necessary to keep the bulbs from freezing. There is always more or less loss in storing onions, as many of the bulbs sprout, especially if they were not thoroughly cured; and others will decay, even though they have been only slightly bruised. In any case there will be a large shrinkage, and if the ventilation and temperature are not closely attended to, large losses may result.

Onions are sometimes kept by allowing them to freeze. If they can be kept frozen and allowed to thaw out gradually just before marketing, no harm results. But successive freezing and thawing injures the bulbs. In general this method of keeping onions cannot be commended.

Insects and Diseases. Fortunately but few insect pests or plant diseases have appeared in Colorado. Grasshoppers occasionally feed on the tops, but they do not often appear until comparatively late in the season, after alfalfa and similar crops have been harvested. They may be successfully combated by scattering poisoned bran along the sides of the field. The mixture is made

in the proportion of one pound of Paris green to twenty pounds of bran, with enough water to thoroughly moisten the mass.

A minute insect known as thrips is present every year. It sucks the juice from the leaves, causing them to have a sickly, blighted appearance. These insects do considerable damage, especially in hot, dry seasons; but as yet no method of combating them is in use.

Bulletin 82. June, 1903.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Colorado Irrigation Waters and Their Changes.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

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COLORADO IRRIGATION WATERS AND THEIR CHANGES.

BY WM. P. HEADDEN.

§ 1. The irrigation waters used in this State are largely furnished by the melting of the snows which accumulate in the higher portions of the mountains during the latter part of autumn, winter, and early spring. The springs feeding our streams are for the most part such as owe their waters to the same source, and are simply the reappearance of these waters retained by the valley soils, which are for the most part shallow and store but a small amount of water, the most of it being free to come down early in the season, before the middle of July.

§ 2. Our rivers do not descend very far into the plains before their waters are diverted from their natural courses, either to be stored or used immediately for the purposes of irrigation. The water supply is becoming a question of such importance and commands so high a price that large expenditures are being made to prevent the storm and flood waters from going to waste by running down to lower levels.

§ 3. The simple diversion of the waters from their natural courses does not change their character provided the character of the course is not changed. This, however, is not the case. These waters flow but short distances through mountainous and sparsely populated sections of country, where the water entering them from the adjacent country is of the same character as that of the stream itself. The collecting grounds are for the most part covered with a thin granitic soil bearing some forest and other mountain vegetation; but a very considerable area consists of naked schists and granites. The lower portions of these streams usually flow through fertile valleys, often under cultivation. The waters are sometimes diverted in the higher portions of their courses and at every point below this where their volume and the contour of the country will permit.

§ 4. The Cache a la Poudre river flows for the first fifty miles of its course over bowlders of schist and granite, and then over gravel and sand of the same character. The North Fork flows for a portion of its course through jura-triassic strata, into which it has cut its bed before emptying into the Poudre. The chief foreign constituents, that is other than those dissolved out of the rocks

of its drainage area, contained in this water are such as are introduced by the people living along its banks. The water of the Cache a la Poudre is an excellent water usually containing less than three grains of solids to the imperial gallon. The water furnished to the inhabitants of Fort Collins is taken from the Poudre about six miles below the point where the North Fork joins the Poudre, and is a mixture of Poudre and North Fork water plus a notable quantity of seepage. This water varies in the amount of total solids contained from 2.5 grains per imperial gallon to 13.5 grains, which is the maximum observed. The former sample was taken when the river was high and the influence of the North Fork and the seepage water together was not perceptible. The latter was taken when the Poudre was low. Their influence is shown by the notable increase in the amount of the total solids present.

§ 5. The conditions given for the Poudre hold for all the streams north of the Arkansas, and for those of the San Luis valley, so long as they are mountain streams. When their waters leave the mountains their courses are over rocks of younger geological formations, from which they receive waters of different quality, and their character is materially changed.

§ 6. I shall give analyses of waters from other streams, but that of the Poudre will be the only one treated of in detail. The considerations which have led me to confine myself to the study of the Poudre river water to so great an extent as I have done are evident: First, the water of the Poudre irrigates at the present time, as much if not more land than that of any other stream within the State; Second, it flows through our home valley, is easy of access, and we have fuller data and more intimate knowledge of it than of any other stream in the State; Third, irrigation has been practiced in this valley almost as long if not as long, as in any other portion of the State (a few sections where irrigation was practiced by the Mexicans excepted), extending over a period of forty-three years; Fourth, the oldest and at the same time an extensive system of reservoirs whose beginning dates back to 1875, has been made to supplement the summer flow of the river.

§ 7. Under these conditions the flow of the return waters has already been established, the first exaggerated effects of irrigating this land have passed away, and the rate at which the return waters are carrying the soluble salts from the soil has presumably approached, if it has not already reached the point, at which it will remain for years to come. The same may be assumed to be true in regard to the character of the salts taken into solution.

§ 8. In this section the period of drainage has begun, land having become valuable enough and water in such demand that drainage has already been instituted for the double purpose of preserving the land from being water-logged or seeped, and for render-

ing the water available for irrigating other land. From this time on water will be made to do duty repeatedly in the production of crops, even more so than at present, especially if the fall of the river and other conditions will permit it.

§ 9. For these reasons the Poudre presents the best subject, and the present is probably the most opportune time that has yet presented itself for such a study. The chemical questions relative to the composition of the return waters will become more involved within the next few years than they are now, because an increasing percentage of such water will have been used repeatedly before it makes its appearance as such in the river. Some of it will have passed into storage reservoirs and suffered whatever changes that may take place during the time of storage. One of the largest reservoirs within this valley has recently been completed, the purpose of which is to collect and render available waste and seepage or return water.

§ 10. The course of the river after it issues from the canyon is over the jura-triassic and cretaceous formations. The character of the river bed has but a slight influence upon the composition of the water compared with that of the return waters, the percentage of which increases as one goes down the stream; not simply because there is an increase in the number or size of the inflowing streams and springs, but also because of the amount of water which has been taken out in the upper parts of the river. There are six larger and several smaller ditches taking water from the Poudre between the mouth of the canyon and the town of Fort Collins. These ditches take at least four-fifths of the water flowing in the river above the first ditch. The gagings show that there is a small loss of water between the gaging station in the canyon, and a point below Bellvue, the city water works; but from this point on to the mouth of the river there is an irregular but increasing gain. The sewage from the town of Fort Collins, and also that of the College, which is an independent system, flows into the river below the town. The college system also carries a considerable volume of drainage water. The total volume of water returned to the river in this way is large, representing the sewage from a population of 5,000; but the total mineral matter added to the river water by the drainage is probably greater than that contained in the sewage, and this represents but a very small fraction of the mineral substances brought in by the return waters.

§ 11. There is much irrigated land in this district, from which the seepage and waste waters together with waste from the ditches, begin to return, as shown by the measurements of the river several miles above Fort Collins. There is a gain beginning a little way below the town of Bellvue, which increases as we go down the river, until at its mouth the total increase reached, in 1895,

164.4 second feet; and in 1901, 167 second feet. This gain, or the amount of water returning to the river, varies for different sections of the river, and also from year to year. The minimum flow of return waters which I find given was in March, 1894, when it amounted to 82.3 second feet. (Bulletin No. 33 of this Station.) The percentage of seepage water in the river at any given point will evidently vary from time to time, but taking the whole course of the Poudre from below Bellvue down to its mouth the amount varies from a small amount to 100 per cent. In order to obtain river water free from seepage, it is necessary to take it above the headgate of the ditch furthest up the stream; in fact we found it advisable to take it above the mouth of the North Fork.

§ 12. The river water as it is delivered to the town of Fort Collins, for domestic consumption, is, from a chemical standpoint, a good water for domestic purposes; but a comparison of it with the river water taken further up the stream shows that it has already suffered a considerable change, due to admixture of seepage which has found its way to the river. The object had in view in taking the samples of this water was not to examine it to determine its fitness as a potable water, but simply as a part of the larger questions relative to the changes suffered by the water when used for the purposes of irrigation.

THE CACHE A LA POUDRE RIVER WATER.

§ 13. The Cache a la Poudre, very generally called the "Poudre," and its tributaries, drain a mountainous area of about 1,050 square miles before it enters the plains section. These 1,050 square miles of drainage area present a varied surface, some of which is wooded or covered with other vegetation, much of it being naked rocks; but whether covered with a thin mountain soil, a rich valley soil or rotten rocks, there is everywhere one constant condition. The rocks are largely granite, and the soil, very naturally, is granitic too. The waters flow over granite bowlders, are retained in the interstices of granitic sands or soils, and whatever mineral matter is taken into solution by the waters is derived from the minerals making up the granite, gneiss or schist, as the case may be. The snows on the mountains by their melting yield the water which finds its way to the valleys to be later used for immediate irrigation or stored for subsequent use. I shall endeavor to follow the changes produced in the composition of this water from the time it melts, when I shall assume it to be practically pure water, until it leaves the Poudre to join the Platte. There are many difficulties in this study, and I shall be compelled to leave many questions wholly unanswered and others with very general answers.

§ 14. The most surprising change in the series suffered by this water is perhaps the very first one, that is, the change produc-

ed in the content and composition of its mineral constituents while it is still within its mountain area and before it debouches from its canyon into the plains. As snow we may consider it free from any mineral content, and as river water it is very pure, but not free from mineral matter. It has already been at work upon the rocks. It has taken from the air some carbon dioxid and gotten a little more from the decaying organic matter with which it has come in contact, and with this to aid it, it has taken up from 2.5 to four or five grains of mineral matter to each imperial gallon that flows through its canyon. Even its flood waters find time enough to dissolve out of the rock the smaller quantity, i. e., 2.5 grains per imperial gallon. It may seem to some an incredible thing that this should be so, but we can imitate it, and show that in a comparatively short time pure water in the presence of carbon dioxid can take up upwards of 4.5 grains of mineral matter per gallon from these very rocks, or rather from some of their constituents. There is no doubt about either the fact or the source from which the mineral content of the water is derived. The amount dissolved may surprise us, and we may wonder why the rocks have lasted so long, but we all know that the surface of the rocks is worn and that many of them are rotten for many feet below the surface, even crumbled so that they can be moved with pick and shovel. Some of the streets of the city of Denver are covered with such material as are our walks and drives. Those of us who have traveled on almost any of our mountain railroads have seen cuts of five, ten or more feet in depth made through such material, aggregating many miles. The geologist finds everywhere the products left by the water; sometimes they are thick beds of clay, at others simply rock debris. He sees in the soil a testimony of its persistent action whereby it has loosened the bonds which bound the little grains now constituting the particles of soil to their fellows, dissolving some, changing others, and carrying still others away. Each step that he describes is susceptible of observation or direct proof, however slowly they may seem to proceed or however great their aggregate results.

§ 15. The water of the Poudre, as already stated, is derived from the melting snows of the Laramie and Medicine Bow ranges, but by the time it has reached its canyon it has taken up a considerable amount of matter from the rocks. If we assume the flow to be 300 second-feet and the dissolved matter to be 2.25 grains per imperial gallon, the amount of mineral matter removed from its drainage area per day would be close to twenty-six tons, or taking the specific gravity at 2.6, almost 320 cubic feet of solid rock material every twenty-four hours. Even these figures represent only the amount carried at this point in the course of the stream, and not the total chemical work done by the water, for it is very probable that a series of changes have taken place, beginning with the

first action of the pure water upon the rock particles whereby a part of the substances originally dissolved has been removed, and it is only that portion which has escaped removal from solution that we find in the water in the lower mountain section of the stream. In addition to this the remaining rock has also been altered, and its new condition represents a further fraction of the work accomplished by the water.

§ 16. This is, in general terms, a statement of the process by which our waters obtain their burden, be it great or small, of mineral matter in these mountainous sections where the principal or only source from which they obtain it is the constituent minerals of the rock by direct attack upon them; and the products so formed are not modified, except by the agencies universally present, as for instance, the air or the interaction of solutions, differing only slightly from one another. This is wholly changed, as we shall see, when we come to such conditions as prevail in the soils. A fuller consideration of the changes which we are able to trace will I think help us materially, both in answering the questions arising relative to the points of attack, the course of the changes taking place in the minerals, and prepare the way for a better understanding of the manner of formation and properties of the soil. The object of this bulletin, however, is to take up the study of the river water and the changes it suffers when used for irrigation, in so far as we may be able to unravel them; and if we do not succeed in a satisfactory measure we still hope that the data accumulated may be interpreted by others to the furtherance of the object here attempted.

§ 17. In Bulletin No. 65, entitled "A Soil Study, Part III., The Soil," I stated that, in my own view, the study reduced itself to an investigation of the various decomposition products of felspar; not that other minerals might not be participants in these changes, but simply as a fact in this case, that we had an orthoclase felspar to deal with together with the products of its alteration. What these products are will undoubtedly vary under different conditions. Two conditions, however, obtain everywhere; the presence of water and of carbonic acid, and to these we appeal as the chief agents in the changes whereby, among others, the food elements contained in the rock particles of the soil are made available. It has been customary to consider certain mineral combinations which were supposed to be formed by the action of various agents upon the rock particles within the soil as intermediate agents, serving the purpose of retaining and conveniently giving up certain elements of plant food. This function has been attributed to a group of minerals called zeolites, and to express this property of the soil we find the expression zeolitic constituents. So far as the study of the action of water on felspar goes, it throws no light upon this view, and we de-

tect nothing favoring the assumption of the formation of zeolites in this manner. The general trend of the evidence is that there is a greater similarity to the conditions existing in veins than to those conditions where zeolites are formed. The theory of the existence of zeolitic constituents within the soil is convenient for many reasons, but it is doubtful whether it is correct for all soils, if it is for any.

§ 18. In Bulletin No. 65 I have shown to how great an extent our soils are made up of felspar particles, and have also held that they owe their origin to the disintegration of the granites and gneisses of the Front or Colorado range. It clearly follows that the present rivers or the streams which they now represent, have contributed in the past, as they are now doing, to this work. The contribution made by the Poudre being, according to the assumption previously made, 320 cubic feet of solid rock taken into solution daily from the area of 1,050 square miles. This result is entirely apart from its mechanical action by which a manifold greater mass is broken down and moved from one place to another. It may not be removed very far, but it is on its way to a new resting place.

§ 19. The statement that the clear water of the river which we are accustomed to think of as pure snow water, is daily carrying not less than twenty-six tons or 320 cubic feet of solid rock from the mountains down to the plains, is so large that it will undoubtedly strike the average person as over-estimated. But such is not the case, for by direct experiment we have succeeded in bringing into solution a little more than twice the amount per gallon assumed to be present in the calculation.

§ 20. Finely powdered felspar was taken and treated for fourteen and one-half days with water and carbonic acid, and we found that the solution had dissolved out of the felspar constituents equivalent to 4.53 plus grains per gallon, and this amount, 4.536 grains, would not be considered a large quantity of mineral matter to be found, even in the water of mountain streams. This would give us rather more than double as much, or 640 cubic feet per day instead of 320, as previously assumed. The aggregate removed, whether it be measured in tons or cubic feet, is a considerable quantity. The range of total solids contained in the Poudre water is from 2.6 grains to 4.6 grains; in other words, assuming a flow of 300 second-feet, the amount actually removed daily lies between 320 and 640 cubic feet of rock material weighing about 26 tons for the lower figures or 52 tons for the higher.

THE SOURCE OF THE MATERIAL.

§ 21. I have alluded to the felspar as the source from which the water obtained its mineral matter in this case. It is not in-

tended to assert that this mineral is the only one on which the water, carbonic acid, and whatever other agencies co-operate with them act, but it is the principal one; and this is true to such an extent that we may neglect all others. The prevailing rock within the drainage area is either granite, gneiss or mica schist. There are a few eruptives within this area, and locally a little hornblende-schist occurs; but these form no large areas, so we confine ourselves to the consideration of the felspar of the granite, which is an orthoclase. This statement does not exclude the occurrence of other varieties, but they are altogether subordinate. The preceding facts constituted one reason why I chose a typical orthoclase for experimentation. A second reason was the observation that our soil consists largely of grains of this mineral. The results of experiments with this mineral then give us a measure whereby to judge to what extent the Poudre water obtains its mineral matter from this source; and, secondly, a clue as to what is going on in the soil, which, however, is only of incidental interest at this time.

§ 22. A portion of felspar, orthoclase, was ground very fine, passing through a 100-mesh sieve, and treated for 22 days with water containing carbon dioxid in solution. At the expiration of this time air was caused to pass through it whereby any ferrous salts would be oxidized and the ferric hydrate precipitated. By doing this we imitate the action which we see taking place in the river waters, especially when derived from springs in whose waters iron may be held in the form of ferrous salts. We found in this case that we obtained a copious precipitate of the hydrated ferric oxid. The filtered water was evaporated in platinum dishes to avoid obtaining any silica or potash, as might have been the case had we used a porcelain or copper dish to evaporate in. The amount of total solids obtained corresponded to 1.68 grains to the imperial gallon. I will here observe that the results of all the experiments that I made indicate that the amount dissolved is proportional to the time the water is in contact with the felspar, at least for such times as my experiments continued, other conditions being the same. The residue obtained had the following composition:—

TABLE I.—ANALYSIS OF PORTION OF FELSPAR DISSOLVED BY WATER AND CARBONIC ACID IN TWENTY-TWO DAYS.

Analytical Results.	*Per Cent.*
Silicic Acid	14.353
Sulfuric Acid	9.879
Carbonic Acid	19.874
Phosphoric acid	0.381
Chlorin	3.170
Aluminic Oxid	1.119
Ferric Oxid	0.136
Calcic Oxid	23.412
Strontic Oxid	Heavy trace.
Magnesic Oxid	1.919
Potassic Oxid	11.279
Sodic Oxid	6.491
Lithic Oxid	Trace.
Ignition	25.337
Sum	117.370
Less carbonic acid and oxygen equivalent to chlorin *	20.588
Total	96.782

Combined.	*Per Cent.*
Calcic Sulfate	16.806
Calcic Carbonate	29.432
Magnesic Carbonate	4.013
Potassic Chlorid	6.668
Potassic Carbonate	10.367
Sodic Carbonate	3.736
Sodic Phosphate	1.257
Sodic Silicate	6.765
Aluminic Oxid	1.119
Ferric Oxid	0.136
Ignition	5.464
Excess Silicic Acid	11.018
Total	96.783

* Note.—This residue was first dried on a water bath and afterwards in a water oven, as I knew from analyses already made that there was in all probability a considerable excess of silicic acid present in a most favorable form to react with any alkaline carbonates present, which I wished to avoid. I fear that a reaction between the silicic acid and these carbonates took place during the long continued boiling and heating on the water bath necessary to evaporate the water to dryness, especially as the quantity of water was large (in this instance about twenty gallons), and the vessel in which the evaporation was carried on was small. It is also certain that on ignition, even at a gentle heat, the silicic acid reacts upon the carbonates, and perhaps other salts also, causing an excessive loss over that of moisture and organic matter. The ignition in this case was made very cautiously, but there is evidently an uncertainty about its correctness. I have repeatedly observed that in cases of ignition of such residues, even when there was not a sufficient excess of silicic acid to account for it, that the carbonic acid was completely expelled by a very gentle ignition. This may have indicated that the carbonic acid was in combination with lime as calcic carbonate; but the ignition was so gentle that I doubt whether it would have sufficed under ordinary conditions to have decomposed a corresponding amount of calcic carbonate. Other methods of determining this loss might have been adopted, but the amount of material at my disposal made ignition the most feasible one, it being quite certain that there was no loss of bases; and as there still remains an excess of acid, the result emphasizes this fact. I do not know in this case that the whole of the CO_2 was expelled, but I have assumed it to have been, and have accordingly taken it together with the oxygen equivalent to the chlorin found from the sum of the results obtained.

§ 23. The preceding experiment does not stand alone, and was really not our principal one in this connection, but as the statement of others would add only cumulative evidence of the correctness of the conclusion that the source of the inorganic matter contained in the Poudre water is the felspar occurring everywhere

throughout the drainage area, the others wili not be given in this place

§ 24. The first two analyses of the Poudre water that I shall give ought, perhaps, to be given in the reverse order, but as I intend to give the rest of the analyses in regular order as we go down the river, I will not deviate from it in the case of these. The only reason which would justify me in doing so would be the fact that, in the case of the second analysis I know that at least one-half of the water flowing in the river at the time the sample was taken, came down the North Fork as flood water, resulting from a heavy rain which fell in the mountains of the remoter portions of its drainage area.

§ 25. For the sake of completeness and for subsequent convenience of reference I shall give with each chemical analysis the sanitary analysis of the sample; but as the latter is of subordinate importance in our study, it will follow the chemical analysis. My object in this bulletin is not to deal with the potability of the waters used for irrigation, but to learn as much as possible about the changes that they suffer and how much they add to the fertility of the land, if any, by virtue of the elements of plant food that they contain in solution, and incidentally in suspension also. The chemical analysis gives us the amount and approximately the character of the inorganic salts held in solution, and I have adopted the ordinary sanitary analysis as the means of determining the various forms in which the nitrogen occurs, as well as its total quantity. In regard to the chlorin given in the two forms of analysis, it will be observed that the amount given by the sanitary analysis is slightly higher than that given by the chemical analysis.

TABLE II.—ANALYSIS OF CACHE A LA POUDRE WATER, SAMPLE TAKEN ABOVE THE NORTH FORK, NOV. 3, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silcic Acid	20.871	0.6053
Sulfuric Acid	6.928	0.1946
Carbonic Acid	20.790	0.6029
Chlorin	3.575	0.1037
Sodic Oxid	12.931	0.3750
Potassic Oxid	2.949	0.0855
Calcic Oxid	18.741	0.5238
Strontic Oxid	Trace	Trace
Magnesic Oxid	4.336	0.1257
Ferric and Alu. Oxids	0.388	0.0113
Manganic Oxid	0.063	0.0018
Ignition	[9.233]	0.2678
Sum	100.805	......
Oxygen Equiv. to Chlorin	.805	......
Total	100.000	2.8974

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	11.782	0.3417
Calcic Carbonate	24.781	0.7186
Magnesic Carbonate	9.063	0.2628
Sodic Chlorid	5.899	0.1711
Potassic Carbonate	4.325	0.1254
Sodic Carbonate	9.146	0.2652
Sodic Silicate	8.772	0.2544
Ferric and Alu. Oxids	0.388	0.0113
Manganic Oxids	0.063	0.0018
Ignition	[9.233]	0.2678
Sum	83.452	......
Excess Silicic Acid	16.546	0.4798
Total	99.998	2.8999

Total solids, 2.9 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	41.4286
Chlorin	1.9804
Nitrogen as Nitrates	Trace.
Nitrogen as Nitrites	None.

	Parts Per Million
Saline Ammonia	0.0350
Albuminoidal Ammonia	0.0900
Oxygen Consumed	2.5500

TABLE III.—ANALYSIS OF CACHE A LA POUDRE WATER, SAMPLE TAKEN 150 FEET ABOVE HEADGATE OF LARIMER COUNTY DITCH, JULY 30, 1902.

Analytic Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	20.542	0.5341
Sulfuric Acid	4.951	0.1287
Carbonic Acid	21.626	0.5622
Chlorin	7.619	0.1980
Sodic Oxid	8.874	0.2307
Potassic Oxid	3.286	0.0854
Calcic Oxid	23.884	0.6209
Magnesic Oxid	5.147	0.1338
Ferric and Alu. Oxids	0.894	0.0232
Manganic Oxid	0.093	0.0024
Ignition	[4.802]	0.1248
Sum	101.718	2.6443
Oxygen Equiv. to Chlorin	1.718	0.0446
Total	100.000	2.5997

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	8.420	0.2189
Calcic Carbonate	36.431	0.9471
Magnesic Carbonate	10.758	0.2797
Sodic Chlorid	12.573	0.3276
Potassic Silicate	5.391	0.1402
Sodic Silicate	4.342	0.1129
Ferric and Alu. Oxids	0.894	0.0232
Manganic Oxid	0.093	0.0024
Ignition	4.802	0.1248
Sum	83.704	......
Excess Silicic Acid	16.296	0.4237
Total	100.000	2.6005

Total solids, 2.6 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total solids	37.1400
Chlorin	2.8300
Nitrogen as Nitrates	0.1000
Nitrogen as Nitrites	None

	Parts Per Million.
Saline Ammonia	0.0200
Albuminoidal Ammonia	0.3400
Oxygen Consumed	1.6570

TABLE IV.—ANALYSIS OF CACHE A LA POUDRE WATER, SAMPLE TAKEN FROM FAUCET IN CHEMICAL LABORATORY, MAY 23, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	36.180	1.664
Sulfuric Acid	5.180	0.238
Carbonic Acid	20.860	0.960
Chlorin	Trace	Trace
Sodic Oxid	8.000	0.368
Calcic Oxid	15.960	0.734
Magnesic Oxid	5.060	0.233
Ferric and Alu. Oxids	2.290	0.105
Manganic Oxid	Trace	Trace
Ignition	6.470	0.298
Sum	100.000	4.600
Oxygen Equiv. to Chlorin	Trace.	
Total	100.000	4.600

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	8.800	0.405
Calcic Carbonate	22.000	1.012
Magnesic Carbonate	10.580	0.487
Sodic Carbonate	13.680	0.629
Ferric and Alu. Oxids	2.290	0.105
Manganic Oxid	Trace	Trace
Ignition	6.470	0.298
Silicic Acid	36.180	1.664
Total	100.000	4.600

Total solids, 4.60 grains per imperial gallon.
Saline Ammonia, 0.00740 parts per million.
Albuminoidal Ammonia, 0.00280 parts per million.

TABLE V.—SAMPLE TAKEN FROM FAUCET IN CHEMICAL LABORATORY, SEPT. 21, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	8.050	0.596
Sulfuric Acid	15.392	1.139
Carbonic Acid	22.905	1.695
Chlorin	2.248	0.166
Sodic Oxid	8.095	0.599
Potassic Oxid	0.886	0.065
Calcic Oxid	29.067	2.151
Magnesic Oxid	7.750	0.573
Ferric and Alu. Oxids	0.317	0.023
Manganic Oxid	0.050	0.004
Ignition	5.884	0.435
Sum	100.644	7.446
Oxygen Equiv. to Chlorin	0.506	0.037
Total	100.138	7.409

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	27.174	1.937
Calcic Carbonate	32.631	2.415
Magnesic Carbonate	16.272	1.204
Potassic Chlorid	1.402	0.104
Sodic Chlorid	2.611	0.193
Sodic Carbonate	0.089	0.006
Sodic Silicate	13.116	0.971
Ferric and Alu. Oxids	0.317	0.023
Manganic Oxid	0.050	0.004
Ignition	5.884	0.435
Sum	98.546	7.292
Excess Silicic Acid	1.591	0.118
Total	100.137	7.410

Total solids, 7.4 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	198.5000
Chlorin	5.7100
Nitrogen as Nitrates	0.0400
Nitrogen as Nitrites	0.0010

	Parts Per Million.
Saline Ammonia	0.0250
Albuminoidal Ammonia	0.0571
Oxygen Consumed	1.5450

TABLE VI.—SAMPLE TAKEN FROM FAUCET IN CHEMICAL LABORATORY, SEPT. 6, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	6.123	0.6245
Sulfuric Acid	18.333	1.8699
Carbonic Acid	23.266	2.3731
Chlorin	1.035	0.1055
Sodic Oxid	6.501	0.6631
Potassic Oxid	1.883	0.1921
Calcic Oxid	29.769	3.0364
Strontic Oxid	0.219	0.0223
Magnesic Oxid	8.684	0.8857
Ferric and Alu. Oxids	0.168	0.0171
Manganic Oxid	0.110	0.0112
Ignition	[4.144]	0.4226
Sum	100.235	......
Oxygen Equiv. to Chlorin	0.235	......
Total	100.000	10.2235

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	31.179	3.1802
Calcic Carbonate	30.199	3.0802
Magnesic Carbonate	18.152	1.8515
Strontic Carbonate	0.312	0.0318
Potassic Carbonate	1.338	0.1364
Sodic Chlorid	1.708	0.1742
Potassic Silicate	1.593	0.1614
Sodic Silicate	11.035	1.1255
Ferric and Alu. Oxids	0.168	0.0171
Manganic Oxid	0.110	0.0112
Ignition	[4.144]	0.4226
Sum	99.938	......
Total	99.938	10.1921

Total solids. 10.2 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total solids	145.7143
Chlorin	19.8040
Nitrogen as Nitrates	0.1000
Nitrogen as Nitrites	None
Saline Ammonia	0.1200
Albuminoidal Ammonia	0.0500
Oxygen required *	1.2450

* Note.—The preceding analyses are expressed in two different units: In per cent. and grains per imperial gallon, for ordinary chemical analysis, and parts per million, for the sanitary analysis. I believe that there is no inconvenience caused by this, as the average reader will think of 3.1802 grains per gallon more readily than of 45.4314 parts per million. The term gallon suggests a common measure, as does also the term grain. If any one wishes to convert the term grains per imperial gallon into parts per million to suit his convenience he has simply to multiply by one hundred and divide by seven, which is easily done.

§ 26. The first three of these analyses represent the water of the Cache a la Poudre river as it issues from its mountain section without being modified by waters coming from the surface soil or from the strata of the jura-triassic or cretaceous formations. In order to make our view more general, and to save repetition, we will here include the waters of the Boulder and the Clear Creek, the analyses of which will be given later. The general similarity of the analyses, especially of the analytical results, to those obtained by the analysis of the residue obtained by the evaporation of the water with which we had treated the felspar, leaves no doubt but that the sources of the different residues were the same, and we are justified in considering the felspar which occurs abundantly throughout the drainage areas the source from which the Poudre, the Boulder, and Clear Creek obtain their mineral constituents.

§ 27. This fact is not surprising except when we attempt to express the amounts removed in figures, for everyone conversant with the rocks of the country knows that the predominant minerals are felspar, quartz, and mica, of which the quartz is the least easily attacked by water. The experiment given shows that it is a fact that this is the source of the silica, potash, lime, etc., contained in the water.

§ 28. The presence of sulfuric acid and chlorin in these waters was not easily explainable. In the jura-triassic strata we have an abundance of gypsum from which calcic sulphate might be derived, and in fact this was the source from which I considered much of this salt to have been derived; but this could not possibly be the case where the sample was taken before it had come in contact with this formation, or could have received water which had done so. The analysis of the portion of felspar dissolved by water with the aid of carbonic acid shows a surprising amount of each of these constituents—sulfuric acid, over nine per cent., and of chlorin more than three per cent. The carbon dioxid and even the air drawn through the solution was well washed to avoid the introduction of extraneous substances. The water used was freshly distilled, leaving no residue upon evaporation, and failing to show a trace of chlorin. The felspar had been tested for sulfuric acid, and showed a few hundredths of one per cent.; but it was not tested directly for chlorin. The quantity found in its aqueous extract, however, leaves no doubt of its presence. This mineral, felspar, accordingly may furnish the sulfuric acid and chlorin found in our mountain waters, as well as the total solids in general.

§ 29. There is still stronger evidence, if there were need of it, and that is the presence of strontia and lithia in the water. In Bulletin No. 35, in a note upon the ash of alfalfa, I called attention to the fact that strontia was always present, but lithia was not detected in any single instance. Again in Bulletin No. 72 I called attention to the fact that lithia was found to be generally present in the ground waters which I had examined. I do not think that I have tested a single sample of ground water (and I have tested many within the past five years), that failed to show the presence of lithia. The same may be said of the Poudre water. I have also found it present in the waters of the St. Vrain, the Boulder, Clear Creek, and in the water of the Running Lode mine taken at a depth of 825 feet; also in the waters of the South Platte and the Arkansas. Its presence in the waters of the South Platte is not so significant, for there are several springs discharging into this river which I know carry some lithia, but the relative volume of these springs is small, and I am convinced that the lithia found indicates its more general occurrence in the waters of the Platte, and the same may be said of those of the Arkansas, for I doubt whether the small

quantity brought in by the springs could be detected with ease in the quantities of water actually used. Again, the presence of strontia is demonstrable with comparative ease in both the ground waters and the river waters. These facts were difficult to explain, and puzzled me greatly, leading me to doubt the correctness of my observations until frequent repetitions established it as a fact. The presence of these in the felspar and the power of even slightly carbonated water to take them into solution accounts fully and satisfactorily for their general presence in the river and ground waters, and enables us to trace the source from which the water obtains its original content of mineral matter. It further makes it very probable that all the waters flowing out of the area presenting the same general conditions, whether they flow eastward, as in case of our streams, or westward, as in the case of the streams of the western slope, have the same general properties until changed by new conditions.

CHANGES SUFFERED WHILE FLOWING IN BED OF STREAM.

§ 30. The analyses of the Poudre water already given show clearly that such changes take place before the waters have completed any considerable portion of their course. The sample taken above the mouth of the North Fork, Nov. 3, 1902, Table II, was taken at a time when there was no flood water and after a period of good weather. The snows of the preceding season had either disappeared, or were melting so slowly as to have little or no influence upon the flow, so that the water then flowing represented the normal water of the Poudre as nearly as we could obtain it. The samples taken from a tap in the Chemical Laboratory, especially the samples represented by analyses five and six, both taken in the month of September, one in 1900, the other in 1902, represent the same water after it had flowed for a distance of about eight miles to the water works, where it passed into the city mains.

§ 31. The principal difference that we observe is that the amount of total solids has increased from less than three grains (2.9 grains), to 7.4 grains in the first instance, and 10.2 in the second, that is, from two and one-half to three and one-third times the original amount.

§ 32. The water taken in the first sample had probably flowed sixty miles over the bed of the stream, but it had received water of its own kind, coming, as it had, through granitic sands and rocks. The last two samples had flowed only eight miles further, and only a portion of this distance was over a bed of a different character; and yet in a distance of less than eight miles the amount of mineral matter held in solution has been increased by these multiples. The greatest changes, however, have not been

in the amount, but in the character of the mineral matter, which is perhaps best exhibited by the analytical results, showing that the silicic acid in the solid residue, has been reduced in percentage, but almost exactly proportionally to the increase in the amount of total solids. The sulfuric acid has been increased nearly three times in percentage, and consequently a little less than nine times in absolute amount. The amounts of soda and potash have been doubled, but their percentages reduced, while the percentages of lime and magnesia have been greatly increased, and the absolute quantities are six and eight times greater.

§ 33. The extent of this change will be more fully appreciated when we estimate the difference in the total quantity of solid matter carried by the stream in twenty-four hours, as we have done for the river above the mouth of the North Fork. We found that the river carried about twenty-six tons of inorganic material, or, assuming a specific gravity of 2.6 for the solid substances, about 320 cubic feet. Assuming the same data to hold for the river water as it passes the Fort Collins water works ditch, we obtain from 65 to 87 tons, or from 800 to 1,067 cubic feet. Taking the higher figures, we discover an increase of 62 tons, or 747 cubic feet of inorganic matter carried in solution. These figures represent the ratio of salts perfectly, and the actual amounts under the assumed flow, which, however, is too high for an average year. But if we take 150 second-feet, which is below the average, as the flow, it would still represent an increase of 31 tons daily, or about 373 cubic feet of solid matter which enters the river in the section represented, about eight miles long.

§ 34. It is evident that if a proportionate change takes place, as the water proceeds down the river it will soon be so changed that comparisons cannot profitably be made. In the case of our streams this is so greatly complicated by return waters entering the river and by direct flows being taken out for irrigation or storage that no attempt will hereafter be made to compare the results except as to some particular features.

THE EFFECT OF STORAGE.

§ 35. This problem is not at all simple, for the reason that the water collected in reservoirs is not all river water, and in order to present all the conditions faithfully a detailed study of the supply would be necessary, which is clearly out of the question for me to make. I shall present analyses of some of our principal and older reservoirs which are, so far as I know, filled from the Poudre river and receive but relatively little seepage. The amount of seepage so far as I am informed, has never been determined. The amount of rain-water which they receive may be neglected. The concentration due to evaporation is not neg-

ligible, but the amount of salts with which we shall have to deal is so large that in subsequent statements we will take no note of this factor.

§ 36. The evaporation from an unprotected surface of water at Fort Collins is about forty inches per annum, or, considering the Poudre water to carry 2.9 grains per imperial gallon, there would be added to the remaining water 400 pounds of inorganic salts for each acre of surface exposed, and if the average depth of the reservoir were, as is the case in Terry lake, about twenty feet, the difference would be about 0.5 grain per gallon. This increase may be attributed to evaporation, but it is too high, for the water does not remain in the reservoirs the whole year, as here supposed; at least the reservoirs are not full, and the actual increase due to this cause is less than 0.5 of a grain per imperial gallon. That the aggregate amount of inorganic or mineral matter is large is evident. There is, however, but little profit in indulging in calculations of this sort, as they are modifications of the one already made in regard to the amount of dissolved matter daily brought down from the mountains by the Poudre river.

§ 37. The reservoir known as Terry lake has, when full, a surface area of 470 acres, from which forty inches of water evaporate annually, leaving nearly 400 pounds on each acre, or an aggregate of 94 tons of mineral matter for the entire reservoir, which has been dissolved out of the granite of the mountains where the snows have melted. But when this quantity is compared with the figures which we shall have to use to represent the aggregate of salts carried by these reservoir waters, it will be realized that this increase in the mineral matter in such waters due to evaporation can be neglected.

§ 38. I shall give the reservoir waters in order, going down the valley, beginning with the Larimer & Weld, or Terry lake. This may not be the best order, or rather it might be well to omit Terry lake altogether, because it is not typical of the changes which I most desire to set forth, but presents them in so extreme a form as to overshadow the less extreme but probably more representative results shown by the others. This reservoir, however, is one of the oldest and stores 9,000 acre-feet of water, and although the changes presented by the water of this reservoir may be greater than in the other cases, it may alone serve to give a more adequate idea of the real extent and importance of the solvent action of water upon the soils and of the supply of the soluble salts contained and formed therein than the others.

LARIMER & WELD RESERVOIR (TERRY LAKE).

§ 39. This reservoir is situated about two miles north of Fort Collins and is filled principally by water taken from the

Poudre river, the other sources being seepage and storm water from Dry Creek, and seepage and drainage from the adjacent country. Some years these latter furnish a considerable part of the 9,000 acre-feet contained in this reservoir. While this statement is true as to the amount of water furnished, it seems very probable that these sources always furnish an unusually large amount of soluble salts. The Little Cache la Poudre ditch, which carries water from the Poudre river to the reservoir, is a comparatively short ditch and can scarcely collect more than a small part of the salts which we shall presently find contained in the water of the reservoir. The two analyses given below are of samples taken from near the center of the lake and several feet below the surface, just before the water was drawn out, the reservoir being full. The water was slightly yellow and had a slight odor.

TABLE VII—ANALYSIS OF WATER FROM THE LARIMER & WELD RESERVOIR (TERRY LAKE). SAMPLE TAKEN JULY 28, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.125	0.168
Sulfuric Acid	48.089	64.680
Carbonic Acid	4.727	6.358
Chlorin	0.982	1.321
Sodic Oxid	14.935	20.087
Potassic Oxid	0.129	0.174
Calcic Oxid	8.117	10.917
Magnesic Oxid	13.244	17.813
Ferric and Alu. Oxids	0.020	0.027
Manganic Oxid	0.040	0.054
Ignition	9.938	13.367
Sum	100.346	134.966
Oxygen equiv. to Chlorin	0.221	0.297
Total	100.125	134.669

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	19.704	26.502
Magnesic Sulfate	39.741	53.452
Potassic Sulfate	0.237	0.319
Sodic Sulfate	17.574	23.637
Sodic Chlorid	1.620	2.179
Sodic Hydric Carbonate	0.463	0.623
Sodic Carbonate	10.590	14.243
Ferric and Alu. Oxids	0.020	0.027
Manganic Oxid	0.040	0.054
Ignition	9.938	13.367
Sum	99.927	134.353
Excess Silicic Acid	0.125	0.168
Total	100.052	134.521

Total solids, 134.5 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	1,921.4000
Chlorin	24.3000
Nitrogen as Nitrates	0.2000
Nitrogen as Nitrites	2.4000
Saline Ammonia	0.0944
Albuminoidal Ammonia	0.6171
Oxygen required	5.9000

TABLE VIII.—ANALYSIS OF WATER TAKEN FROM THE LARIMER & WELD RESERVOIR (TERRY LAKE), JULY 30, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.117	0.205
Sulfuric Acid	53.967	94.766
Carbonic Acid	1.936	3.400
Chlorin	0.872	1.530
Sodic Oxid	15.071	26.465
Potassic Oxid	0.359	0.630
Calcic Oxid	8.893	15.616
Strontic Oxid	0.196	0.344
Magnesic Oxid	13.104	23.011
Ferric and Alu. Oxids	0.063	0.111
Manganic Oxid	Trace	Trace
Ignition	5.441	9.554
Sum	99.822	175 632
Total	99.822	175.632

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	21.606	37.940
Strontic Sulfate	0.346	0.608
Magnesic Sulfate	39.136	68.723
Potassic Sulfate	0.663	1.164
Sodic Sulfate	26.224	46.049
Sodic Chlorid	1.439	2.527
Sodic Carbonate	4.667	8.195
Sodic Silicate	0.237	0.416
Ferric and Alu. Oxids	0.063	0.111
Manganic Oxid	Trace	Trace
Ignition	5.441	9.554
Total	99.822	175.287

Total solids, 175.6 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	2,508.570
Chlorin	28.290
Nitrogen as Nitrates	0.100
Nitrogen as Nitrites	0.010

	Parts Per Million.
Saline Ammonia	0.100
Albuminoidal Ammonia	0.600
Oxygen required	2.283

§ 40. Taking the average of the total solids obtained for these two years, 1900 and 1902, determined in each case when the lake was full, we have 155.02 grains per gallon. The present capacity of the lake being 9,000 acre-feet, these figures give us 27,127 tons as the amount of mineral matter, only 507.5 tons of of which was originally contained in the water, assuming it all to have been taken from the river. This large amount of salts, 27,127 tons, is annually distributed over the land irrigated by this water, or about three tons per acre-foot. At the present time we are less concerned with its distribution, which we will discuss later, than with the question of its source. It matters not whether it is storm water or river water; neither of these contains the fiftieth part of the salts here represented. If it were all river water containing 2.9 grains per gallon, it would account for only about 507 tons, leaving 26,620 tons to be derived from the seepage of a comparatively small area of country. If the whole of the Dry creek seepage were turned into the reservoir, its volume would not seem to be large enough to account for this result. The distance from Terry lake to the North Poudre canal is less than nine miles, and the average width of country which seeps or drains into it is not more than three and one-half miles, at the most thirty-two square

miles. The North Poudre canal was opened about 1884, and all the seepage and waste water arising from irrigation in this area has been washing out this tract for the past eighteen or nineteen years; and as Terry lake is emptied annually, and the water collected from the Dry creek will not average more than one-third of its contents when full, it is difficult to understand how it can furnish so very large an amount of alkali salts at the present time. To present this more clearly, we will give the actual quantities of the three salts constituting the principal part of our alkalies, which are calcic, magnesic and sodic sulfates. Terry lake contained, as the average for the two years, 1900 and 1902, 23,589.63 tons of these salts, represented as follows: calcic sulfate, 5,859.43 tons; magnesic sulfate, 10,616.42 tons; and sodic sulfate, 7,113.78 tons; all calculated as anhydrous salts. The greatest amount that a like quantity of Poudre river water would have contained would have been 59.73 tons of calcic sulfate, and no magnesic or sodic sulfate; but we have estimated that two-thirds of the water filling the lake is taken directly from the river, and the amount of this salt would be 39.82 tons, leaving 5,819.61 tons to come from the Dry creek drainage area, together with all the magnesic and sodic sulfates.

§ 41. I have spoken of the drainage area as though it extended no further northward than the North Poudre canal; this is not strictly correct, but the land under the North Poudre canal is the most northerly irrigated land. I do not know what proportion of the Dry creek water is originally Poudre river water, coming from either the Poudre or the North Fork.

LONG POND.

§ 42. Long pond lies east of Terry lake and within a mile. This reservoir is filled from the Larimer county ditch, and receives much less seepage than Terry lake. It contains about one-half as much water, or about 4,500 acre feet, but presents a proportionately smaller surface. The question, however, of concentration by evaporation, even in Terry lake, is one of a half-grain or less per gallon, and will be neglected. The changes in the water in this lake are much more nearly representative of those usually taking place than is the case with Terry lake.

TABLE IX—ANALYSIS OF SAMPLE OF WATER TAKEN FROM LONG POND AUGUST 1, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.459	0.382
Sulfuric Acid	44.013	11.531
Carbonic Acid	6.653	1.743
Chlorin	1.494	0.391
Sodic Oxid	12.816	3.358
Potassic Oxid	0.799	0.209
Calcic Oxid	16.217	4.249
Magnesic Oxid	10.104	2.647
Ferric and Alu. Oxids	0.225	0.059
Manganic Oxid	Trace	Trace
Ignition	6.934	1.817
Sum	100.714	26.386
Oxygen equiv. to Chlorin	0.336	0.088
Total	100.378	26.298

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	39.401	10.323
Magnesic Sulfate	30.177	7.906
Potassic Sulfate	1.476	0.387
Sodic Sulfate	0.128	0.034
Sodic Chlorid	2.465	0.646
Sodic Carbonate	16.042	4.203
Sodic Silicate	2.959	0.775
Ferric and Alu. Oxids	0.225	0.059
Manganic Oxid	Trace	Trace
Ignition	6.934	1.817
Sum	99.807	26.150
Excess Sodic Oxid	0.570	0.149
Total	100.377	26.299

Total solids, 26.2 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	374.290
Chlorin	7.070
Nitrogen as Nitrates	Trace
Nitrogen as Nitrites	None

	Parts Per Million.
Saline Ammonia	0.050
Albuminoidal Ammonia	0.280
Oxygen consumed	3.296

WARREN'S LAKE.

§ 43. Warren's lake lies six miles due south of Long pond, and is filled from Larimer County No. 2 ditch, receiving a small amount of seepage and waste water. The distance from the head-gate of the ditch to the reservoir is about eight miles. The sample was taken near the gate. Depth of water, ten feet.

TABLE X.—ANALYSIS OF SAMPLE OF WATER TAKEN FROM WARREN'S LAKE, AUGUST 4, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	2.210	0.407
Sulfuric Acid	30.826	5.672
Carbonic Acid	14.284	2.628
Chlorin	3.323	0.611
Sodic Oxid	12.327	2.268
Potassic Oxid	1.361	0.250
Calcic Oxid	19.672	3.620
Magnesic Oxid	9.800	1.803
Ferric and Alu. Oxids	0.400	0.074
Manganic Oxid	0.092	0.017
Ignition	6.434	1.184
Sum	100.749	18.534
Oxygen Equiv. to Chlorin	0.749	0.138
Total	100.000	18.396

Combined	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	47.796	8.794
Magnesic Sulfate	4.064	0.748
Magnesic Carbonate	17.636	3.245
Potassic Chlorid	2.040	0.375
Sodic Chlorid	3.883	0.714
Sodic Carbonate	12.264	2.257
Sodic Silicate	4.482	0.825
Ferric and Alu. Oxids	0.400	0.074
Manganic Oxid	0.092	0.017
Ignition	6.434	1.184
Sum	99.191	18.233
Excess Sodic Oxid	.818	0.151
Total	100.009	18.384

Total solids, 18.4 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total solids	262.860
Chlorin	9.900
Nitrogen as nitrates	0.100
Nitrogen as nitrites	0.001

	Parts Per Million.
Saline ammonia	0.180
Albuminoidal ammonia	0.420
Oxygen consumed	4.114

WINDSOR RESERVOIR.

§ 44. The capacity of this reservoir is 14,000 acre-feet and it is filled by the Larimer & Weld canal with water taken from the Poudre below the town of Laporte. The reservoir lies twelve miles east and five miles south of the headgate of the ditch. The actual length of the ditch through which the water flows is probably not far from 13.5 miles. The lake was full at the time the sample was taken. Its owners began to draw out the water while the sample was being taken. I do not know how much seepage and drainage water gathers in this reservoir. The higher amount of total solids present indicates a considerable accession of such waters. Terry lake discharges its water through the same canal that fills the Windsor reservoir, but as I understand the matter, these two reservoirs belong to different companies, and as both reservoirs were full at the time the samples were taken, it is not probable that any of the salts held in the water of Windsor lake came from Terry lake water, but represent the influence of the area from which the lake receives seepage. This, of course, includes the lake bed itself.

TABLE XI.—ANALYSIS OF SAMPLE OF WATER TAKEN FROM WINDSOR RESERVOIR, AUGUST 5, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.380	0.264
Sulfuric Acid	50.149	34.803
Carbonic Acid	3.854	2.675
Chlorin	1.890	1.312
Sodic Oxid	12.109	8.404
Potassic Oxid	0.541	0.375
Calcic Oxid	13.254	9.198
Magnesic Oxid	12.475	8.658
Ferric and Alu. Oxids	0.289	0.201
Manganic Oxid	0.070	0.049
Ignition	[5.415]	3.758
Sum	100.426	69.697
Oxygen Equiv. to Chlorin	0.426	0.296
Total	100.000	69.401

Combined	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	32.202	22.348
Magnesic Sulfate	37.258	25.857
Potassic Sulfate	1.000	0.694
Sodic Sulfate	10.581	7.343
Sodic Chlorid	3.119	2.165
Sodic Carbonate	9.294	6.446
Sodic Silicate	0.770	0.534
Ferric and Alu. Oxids	0.289	0.201
Manganic Oxid	0.070	0.049
Ignition	[5.415]	3.758
Sum	100.000	69.395
Excess	None	None
Total	100.000	69.395

Total solids, 69.4 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	991.430
Chlorin	27.730
Nitrogen as Nitrates	0.100
Nitrogen as Nitrites	0.001

	Parts Per Million.
Saline ammonia	0.040
Albuminoidal ammonia	0.360
Oxygen consumed	3.634

§ 45. We have in this case, as in that of Terry lake, and in the others to a less degree, a very noticeable increase in the amount of total solids. Taking the capacity of this lake as 14,000 acre-feet (14,004 is the correct capacity) we find that there are 18,894.15 tons of salts held in solution, while a like quantity of Poudre water would contain only 789.5 tons, showing 18,104.6 tons collected by the lake during the period intervening between the two drawings-off—a period of approximately a year. The capacity of Terry lake is 9,000, that of Windsor lake 14,000 acre-feet. Terry lake collected 27,127 tons, and Windsor lake 18,894 tons, of mineral matter in a year. The amount of these salts is very different, the smaller lake or reservoir having collected one-half more than the larger one.

§ 46. The relative quantities of the various salts are also quite different in these cases. For instance, Terry lake collected 5,859.4 tons of calcic sulfate, anhydrous; Windsor lake, 6,083.29 tons. Terry lake collected 10,616.4 tons of magnesic sulfate; Windsor lake 7,029.58 tons. Of sodic sulfate, Terry lake collected 7,113.78 tons; Windsor lake, 1,999.19 tons. Of sodic carbonate Terry lake collected, average of two years, 2,069.25 tons; Windsor

lake, 1,756.02 tons. To the average person, these figures convey but an inadequate idea of the amount of salts dissolved by these lake waters. If we put it, as is sometimes done, in terms of the transportation facilities which would be necessary to move this combined amount, it may give a clearer notion of the quantity of salts moved by these two lakes. The amount of salts carried out by the annual emptying of these lakes is 46,021 tons, which would require 1,534 cars each holding thirty tons, which, allowing 35 feet as the length of a car, would represent a train ten miles long, not including engines.

THE FERTILIZING VALUE OF THESE SALTS.

§ 47. As the water whose composition we have so far presented is used for irrigating purposes, it may not be amiss to discuss the fertilizing value as it is indicated by the various analyses. The only constituent in the ordinary chemical analysis which is of importance in this respect is the potassic oxid. Our soils contain lime enough to meet the requirements of all cultivated crops. The advisability of adding lime because of its chemical action on the soil is left entirely out of the question, and if it were considered, the form in which the lime is present in the waters would render it of little value, except in a very limited range of cases. We will then simply endeavor to find how much potash these waters would add to the soil if the whole of it were retained and were available to plants as food. These assumptions are made for convenience of presentation only, and for the same reason we will make no distinction between the waters of the different reservoirs, but will take them in the aggregate.

§ 48. The capacity of the four reservoirs is 27,672 acre-feet. Allowing two feet per acre, they would together irrigate 13,836 acres of land. The aggregate amount of potassic oxid found in them was 188.06 tons, equivalent to 347.9 tons of sulfate of potash, which would give almost exactly 50 pounds of sulfate of potash per acre irrigated, equivalent to a dressing of 200 pounds of the average kainit of commerce. It will be recalled that the percentage of potash found in the waters was not uniform, that from Warren's lake yielding the highest. It will also be recalled that the Poudre water as taken from the river to fill these lakes furnishes an insignificant part of this potash; therefore, it is evident that the main supply must have come from seepage. Long pond and Warren's lake receive less seepage than the other two, and when we calculate the amount of sulfate of potash which their waters add to the soil irrigated with it, as we have for the four taken together, we find that an acre receives the equivalent of only 31 pounds, instead of 50 pounds; and if we should use water directly from the river, as it comes through the canyon, it would add the

equivalent of only 12.5 pounds. This last quantity is high in proportion to the amount of mineral matter added, owing to the higher percentage of potash present in the total solids.

§ 49. The sanitary analyses show that the changes suffered while the water is stored do not, in their total results, materially affect the quality of the water, the albuminoidal ammonia, and in one instance the nitrites, alone showing material changes. They also show that the amount of nitrogen added in all forms is utterly insignificant—less than four pounds per acre in the most favorable instance.

§ 50. We see that the amount of plant food distributed by means of the irrigation water, whether it be stored water or such as is used directly from the river, is not so great as might have been expected, but its effect, if the potash present is really available for the use of plants, would undoubtedly aid materially in maintaining the fertility of the soil. In the case of the stored water the potash applied in the course of four years would amount to a dressing of 800 pounds of kainit.

§ 51. There is another question, i. e., how much do we add of other salts which are useless and may be deleterious? To this suggestion the answer is that, taking the aggregate results of the four reservoirs, as we did in the case of the potash when we found that the equivalent of 50 pounds of sulfate of potash per acre was added yearly, we find that with this amount of potash there is added 3.49 tons, 6,980 pounds, of other salts. This result seems large, but if we calculate the amount of salts added per acre when two feet of Windsor or Terry lake water is applied, we shall find still larger quantities. Windsor lake is the largest of the four and is intermediate as to the amount of salts held in solution between Terry lake and the others, and we will for this reason analyze the results obtained from the examination of its water. The capacity of the lake is 14,000 acre-feet, and its water holds in solution 18,894.15 tons of total solids. An application of two feet of water per acre will distribute this over 7,000 acres, or 2.7 tons or 5,400 pounds per acre. The potash contained in this is equivalent to 53.6 pounds of sulfate of potash per acre. The calcic sulfate amounts to 1,738 pounds; magnesic sulfate, 2,000 pounds; sodic sulfate, 542 pounds; sodic carbonate, 250 pounds; sodic chlorid, salt, 174 pounds; other substances, 330 pounds.

§ 52. A like application of Terry lake water would add to each acre: potash equivalent to 54.5 pounds of sulfate of potash; 2,604 pounds calcic sulfate; 4,718 pounds of magnesic sulfate; 3,162 pounds of sodic sulphate and 919 pounds of sodic carbonate.

§ 53. The above figures are for anhydrous salts, but they are doubtlessly present in the hydrated condition, and if calculated as such would be represented by large numbers.

THE CHANGES EFFECTED IN THE WATER USED IN IRRIGATION.

§ 54. It seems proper to take up this subject before we present that of the return waters. The changes produced will depend upon the character of the soil irrigated and will probably differ in the case of sod-covered land and in that of land under cultivation.

§ 55. The facts recorded in the preceding paragraphs relative to the changes, which took place during storage for the comparatively short period of one season, clearly indicate that the only proper basis from which to start would be Poudre water taken for direct irrigation and a perfectly typical soil. These conditions might have been met but it would have been with difficulty.

§ 56. The first series of samples taken for the purpose of studying the changes in the composition of the water used in irrigation was taken in 1898, the second in 1899, and the third in 1900, when I availed myself of the opportunity offered by an exceptionally heavy and protracted rainfall whereby the water plane, as indicated by the hight of the water in the wells dug in different parts of the plot, was raised to within from 1.0 foot to 0.3 of a foot of the surface. The water in this case being rain water, or water produced by snow melting on the ground, eliminated the question of its composition.

§ 57. The water which I used in the following experiments in 1899 was Poudre water mixed with some seepage, but the plot of ground was not typically good soil but rather an alkali soil. Originally this soil was in a bad condition, but it had been improved by cultivation at the time this experiment was made and a part of it was then in excellent condition. The results therefore may represent those of actual practice more nearly than if the whole plot had been in the very best condition, but it clearly involves the question of alkali. It is a difficult matter to find any land where the drainage is not perfect which is entirely free from this question, especially when considered from a chemical standpoint. The instances of Terry and Windsor lakes accumulating in a single season 27,127 and 18,894 tons of salts respectively, after having been in use as storage reservoirs for at least 12 years, is suggestive of a goodly supply, particularly when we consider the comparatively small area from which these quantities of salts were collected.

§ 58. In 1898 the only water at my disposal was seepage water and the supply of this was limited. The water plane was moderately low and was raised from one to two feet in different parts of the plot. The water in the wells obtained its maximum hight in from one to five days and then fell, at first rapidly, afterwards gradually, until it reached the lowest point for the season—the maximum fall being 4.3 feet. The changes in the water will be evident from the following analyses:

TABLE XII—ANALYSIS OF WATER AS IT FLOWED ONTO PLOT JULY 8 AND 9, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.885	0.942	Calcic Sulphate	51.366	25.683
Sulfuric Acid	40.389	20.195	Magnesic Sulfate	15.272	7.636
Carbonic Acid	9.245	4.622	Magnesic Chlorid	4.296	2.148
Chlorin	3.479	1.740	Potassic Chlorid	0.567	0.284
Sodic Oxid	13.149	6.575	Potassic Carbonate	0.735	0.367
Potassic Oxid	0.859	0.429	Sodic Carbonate	21.728	10.864
Calcic Oxid	21.160	10.580	Sodic Silicate	0.851	0.426
Magnesic Oxid	6.900	3.450	Ferric and Alu. Oxids	0.077	0.039
Ferric and Alu. Oxids	0.077	0.039	Manganic Oxid	0.058	0.029
Manganic Oxid	0.058	0.029	Ignition	3.261	1.631
Ignition	3.256	1.628			
Sum	100.462	50.229	Sum	98.211	49.107
Oxygen Equiv. to Chlorin	1.784	0.392	Excess Silicic Acid	1.466	0.733
Total	99.678	49.837	Total	99.677	49.840

Total solids 50.0 grains per imperial gallon.

TABLE XIII.—ANALYSIS OF WATER AS IT FLOWED OFF AT MIDDLE OF NORTH SIDE OF THE PLOT JULY 14, 1898.*

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.079	0.791	Calcic Sulfate	29.729	21.791
Sulfuric Acid	46.877	34.361	Magnesic Sulfate	22.064	16.173
Carbonic Acid	2.895	2.122	Potassic Sulfate	2.534	1.857
Chlorin	4.288	3.143	Sodic Sulfate	24.018	17.605
Sodic Oxid	19.419	14.234	Sodic Chlorid	7.076	5.187
Potassic Oxid	1.376	1.009	Sodic Carbonate	6.981	5.117
Calcic Oxid	12.247	8.977	Sodic Silicate	2.138	1.567
Magnesic Oxid	7.353	5.390	Ferric and Alu. Oxids	0.047	0.034
Ferric and Alu. Oxids	0.047	0.034	Manganic Oxid	0.107	0.078
Manganic Oxid	0.107	0.078	Ignition	5.135	3.764
Ignition	5.135	3.764			
Sum	100.823	73.903	Sum	99.829	73.173
Oxygen Equiv. to Chlorin	0.966	0.708	Excess Silicic Acid	0.026	0.019
Total	99.857	73.195	Total	99.855	73.192

Total solids 73.3 grains per imperial gallon.

* It was an accident that enabled us to obtain this sample of run-off water. The water at our disposal for irrigating was not sufficient to produce any off-flow, but we, by an oversight, left our dam in the ditch and our distributing gates open. On the night of the 13th there was a heavy shower in the foot hills and others also having left their ditches open we obtained water enough to produce a slight off-flow. It is plain that the water which came down thus unexpectedly was storm water and was mixed with the water which we had previously been using for irrigation. The actual result was larger than is presented by the analysis. The volume of this off-flow was small and continued for a short time only.

TABLE XIV.—ANALYSIS OF WATER OF WELL C, JUNE 27, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.764	0.993
Sulfuric Acid	44.501	57.851
Carbonic Acid	3.815	4.960
Chlorin	5.521	7.177
Sodic Oxid	21.681	28.186
Potassic Oxid	0.133	0.173
Calcic Oxid	12.489	16.236
Magnesic Oxid	6.677	8.680
Ferric and Alu. Oxid	0.050	0.065
Manganic Oxid	0.031	0.040
Ignition	5.531	7.190
Sum	101.193	131.551
Oxygen Equiv. to Chlorin	1.244	1.618
Total	99.947	129.933

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	30.309	39.401
Magnesic Sulfate	20.048	26.062
Potassic Sulfate	0.246	0.320
Sodic Sulfate	23.439	30.471
Sodic Chlorid	9.108	11.840
Sodic Carbonate	9.191	11.949
Sodic Silicate	1.553	2.019
Ferric and Alu. Oxids	0.050	0.065
Manganic Oxid	0.031	0.040
Ignition	5.531	7.190
Sum	99.506	129.357
Excess Sodic Oxid	0.440	0.572
Total	99.946	129.929

Total solids 130.0 grains per imperial gallon.

* Before irrigation.

TABLE XV.—ANALYSIS OF WATER OF WELL C, JULY 11, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.398	1.620
Sulfuric Acid	48.138	195.823
Carbonic Acid	1.500	6.102
Chlorin	5.504	22.391
Sodic Oxid	17.201	69.975
Potassic Oxid	0.126	0.513
Calcic Oxid	12.046	49.002
Magnesic Oxid	9.290	37.793
Ferric and Alu. Oxids	0.276	1.122
Manganic Oxid	0.070	0.285
Ignition	6.529	26.561
Sum	101.078	411.187
Oxygen Equiv. to Chlorin	1.241	5.046
Total	99.837	406.141

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	29.233	118.918
Magnesic Sulfate	27.894	113.473
Potassic Sulfate	0.233	0.938
Sodic Sulfate	21.738	88.430
Sodic Chlorid	9 080	36.938
Sodic Carbonate	3.613	14.699
Sodic Silicate	0.809	3.290
Ferric and Alu. Oxids	0.276	1.122
Manganic Oxid	0.070	0.285
Ignition	6.529	26.561
Sum	99.475	404.654
Excess Sodic Oxid	0.359	1.460
Total	99.834	406.114

Total solids 406.8 grains per imperial gallon.

* After irrigation.

TABLE XVI.—ANALYSIS OF WATER OF WELL G, JUNE 27, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.498	1.175
Sulfuric Acid	44.062	103.986
Carbonic Acid	3.521	8.309
Chlorin	7.535	17.783
Sodic Oxid	15.055	35.530
Potassic Oxid	0.418	0.986
Calcic Oxid	16.601	39.178
Magnesic Oxid	8.015	18.915
Ferric and Alu. Oxids	0.040	0.094
Manganic Oxid	0.060	0.141
Ignition	5.940	14.018
Sum	101.745	240.115
Oxygen Equiv. to Chlorin	1.698	4.007
Total	100.047	236.108

Combined.	*Per Cent*	*Grs. Imp. Gal.*
Calcic Sulfate	40.299	95.106
Magnesic Sulfate	24.050	56.758
Potassic Sulfate	0.770	1.817
Sodic Sulfate	7.062	16.666
Sodic Chlorid	12.434	29.343
Sodic Carbonate	8.490	20.036
Sodic Silicate	0.790	1.864
Ferric and Alu. Oxids	0.040	0.094
Manganic Oxid	0.060	0.141
Ignition	9.540	14.018
Sum	99.935	235.843
Excess Silicic Acid	0.109	0.257
Total	100.044	236.100

Total solids 236.0 grains per imperial gallon.

* Before irrigation.

TABLE XVII.—ANALYSIS OF WATER OF WELL G. JULY 11, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.337	1.149
Sulfuric Acid	46.106	157.221
Carbonic Acid	3.456	11.785
Chlorin	6.317	21.541
Sodic Oxid	17.165	58.533
Potassic Oxid	1.002	3.417
Calcic Oxid	13.539	46.168
Magnesic Oxid	9.052	30.867
Ferric and Alu. Oxids	0.070	0.239
Manganic Oxid	0.060	0.205
Ignition	4.352	14.840
Sum	101.456	345.965
Oxygen Equiv. to Chlorin	1.423	4.852
Total	100.033	341.113

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	32.866	112.073
Magnesic Sulfate	27.162	92.622
Potassic Sulfate	1.845	6 283
Sodic Sulfate	13.897	47.389
Sodic Chlorid	10.424	35.546
Sodic Carbonate	8 333	28.416
Sodic Silicate	0.684	2.332
Ferric and Alu. Oxids	0.070	0.239
Manganic Oxid	0.060	0.205
Ignition	4.352	14.840
Sum	99.693	339.945
Excess Sodic Oxid	0.337	1.149
Total	100.030	341.094

Total solids 341.0 grains per imperial gallon.

* After irrigation.

TABLE XVIII.—ANALYSIS OF WATER OF WELL B, JUNE 27, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.638	1.347
Sulfuric Acid	46.128	97.422
Carbonic Acid	3.187	6.731
Chlorin	6.745	14.245
Sodic Oxid	16.311	34.449
Potassic Oxid	0.378	0.798
Calcic Oxid	15.898	33.576
Magnesic Oxid	8.021	16.940
Ferric and Alu. Oxids	0.070	0.148
Manganic Oxid	0.060	0.127
Ignition	4.524	9.555
Sum	101.960	215.338
Oxygen Equiv. to Chlorin	1.520	3.210
Total	100.440	212.128

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	38.592	81.506
Magnesic Sulfate	24.068	50.832
Potassic Sulfate	0.696	1.470
Sodic Sulfate	12.552	26.510
Sodic Chlorid	11.130	23.506
Sodic Carbonate	7.685	16.231
Sodic Silicate	0.833	1.759
Ferric and Alu. Oxids	0.070	0.148
Manganic Oxid	0.060	0.127
Ignition	4.524	9.555
Sum	100.210	211.644
Excess Silicic Acid	0.228	0.482
Total	100.438	212.126

Total solids 211.2 grains per imperial gallon.

* Before irrigation.

TABLE XIX.—ANALYSIS OF WATER OF WELL B, JULY 11, 1898.*

Analytical Results	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.453	1.422
Sulfuric Acid	47.321	148.493
Carbonic Acid	2.086	6.546
Chlorin	4.756	14.924
Sodic Oxid	23.015	72.221
Potassic Oxid	0.188	0.590
Calcic Oxid	10.933	34.308
Magnesic Oxid	5.874	18.433
Ferric and Alu. Oxids	0.039	0.122
Manganic Oxid	0.039	0.122
Ignition	5.908	18.539
Sum	100.612	315.720
Oxygen Equiv. to Chlorin	1.072	3.364
Total	99.540	312.356

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	26.540	83.283
Magnesic Sulfate	17.626	55.310
Potassic Sulfate	0.346	1.086
Sodic Sulfate	35.166	110.351
Sodic Chlorid	7.849	24.630
Sodic Carbonate	5.030	15.785
Sodic Silicate	0.920	2.887
Ferric and Alu. Oxids	0.039	0.122
Manganic Oxid	0.039	0.122
Ignition	5.908	18.539
Sum	99.463	312.114
Excess Sodic Oxid	0.076	0.239
Total	99.539	312.353

Total solids, 313.8 grains per imperial gallon.

* After irrigation.

TABLE XX.—ANALYSIS OF WELL A, JUNE 27, 1898.*

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.649	1.399
Sulfuric Acid	46.854	100.017
Carbonic Acid	3.099	6.681
Chlorin	6.115	13.183
Sodic Oxid	15.289	32.963
Potassic Oxid	0.364	0.785
Calcic Oxid	14.685	31.661
Magnesic Oxid	9.581	20.657
Ferric and Al. Oxids	0.040	0.086
Manganic Oxid	0.060	0.129
Ignition	4.754	10.249
Sum	101.490	218.810
Oxygen Equiv. to Chlorin	1.378	2.971
Total	100.112	215.839

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	35.648	76.857
Magnesic Sulfate	28.750	61.985
Potassic Sulfate	0.670	1.444
Sodic Sulfate	11.393	24.563
Sodic Chlorid	10.091	21.756
Sodic Carbonate	7.472	16.110
Sodic Silicate	1.149	2.477
Ferric and Al. Oxids	0.040	0.086
Manganic Oxid	0.060	0.129
Ignition	4.754	10.249
Sum	100.027	215.656
Excess Silicic Acid	0.083	0.179
Total	100.110	215.835

Total solids, 215.6 grains per imperial gallon.
* Before irrigation.

TABLE XXI.—ANALYSIS OF WATER OF WELL A, JULY 11, 1898.*

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.265	1.092
Sulfuric Acid	46.461	191.326
Carbonic Acid	1.984	8.172
Chlorin	6.808	28.033
Sodic Oxid	16.904	69.612
Potassic Oxid	0.088	0.361
Calcic Oxid	10.824	44.572
Magnesic Oxid	10.330	42.539
Ferric and Al. Oxids	0.036	0.149
Manganic Oxid	0.082	0.339
Ignition	8.140	33.521
Sum	101.992	419.716
Oxygen Equiv. to Chlorin	1.534	6.319
Total	100.388	413.397

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	26.267	108.168
Magnesic Sulfate	31.016	127.723
Potassic Sulfate	0.162	0.668
Sodic Sulfate	18.217	75.018
Sodic Chlorid	11.230	46.246
Sodic Carbonate	4.781	19.687
Sodic Silicate	0.368	1.515
Ferric and Al. Oxids	0.036	0.149
Manganic Oxid	0.082	0.339
Ignition	8.140	33.521
Sum	100.299	413.034
Excess Silicic Acid	0.084	0.346
Total	100.383	413.380

Total Solids, 411.8 grains per imperial gallon.
* After irrigation.

§ 59. We probably applied eight inches of water in this irrigation and had a very small off-flow, so small that it may be neglected in any estimate of the changes produced by the application of the water. The whole eight inches may, in this case, be regarded as having entered the soil and as resting for the time-being upon the water plane as it stood before irrigation. That this is not correct is evident from what we have observed to be the effect of a comparatively small rainfall upon the height of the

water plane. Further, there must be a rapid diffusion of salts taking place between the two solutions represented by the ground water, which probably moves upward when the surface is first moistened, and the descending irrigation water. This diffusion may be greatly modified by the soil, but that some diffusion takes place can not be doubted.

§ 60. I see no better way to present the general changes than to compare the ground water as actually found before and after irrigation. This varied in the different wells under observation; it is usually a difference of degree rather than of character. While I know that in some respects I do violence to the facts from minor points of view, I think that by taking the averages of results found, we obtain a faithful view of the general results for the given irrigation and, while this does not answer many questions which arise, it seems the best approach that we can make to a knowledge of what takes place. As we estimate the amount of water applied at the rate of eight inches or two-thirds of an acre-foot, we will make our calculations for this amount throughout. The irrigation was begun on the 8th and the samples taken on the 11th instant and, as we know that some diffusion must have taken place in these three days, we will assume that this took place completely with an equivalent of eight inches of the ground water.

§ 61. The two-thirds acre-foot of irrigation water contained a total of 1,297 pounds of salts in solution; a like quantity of ground water before irrigation contained 5,139 pounds of salts and after irrigation, 9,550 pounds. The ground water as it was taken from the wells after irrigation showed an increase of 4,411 pounds in the salts held in each eight inches of water. If, however, we had mixed eight inches of the irrigation water with a like quantity of the ground water before irrigation, each eight inches should have contained 3,218 pounds. But we find 9,550 pounds which is an excess of 6,332 pounds in each eight inches, representing the actual solution of 12,664 pounds of salts, which is probably nearer correct than the 4,411 pounds. But as we wish to present conservative figures, we adopt the latter and assume that the eight inches of irrigation water applied, dissolved from the soil 4,411 pounds of salts which were previously not in solution. It would, however, be better to say that the result of the irrigation was to set this much salt free, that is, that whatever reactions may have been induced between the salts within the soil, resulted in bringing this additional amount into solution in the ground water. That the irrigation water acts not merely as a diluent is proven by the changed ratio of the salts present, which is best presented as follows:

TOTAL SOLIDS IN GROUND WATER BEFORE AND AFTER IRRIGATION, JUNE 27—JULY 11, 1898.

Ground Water.	*Before Irrigation.*	*After Irrigation.*	*Pounds Gain.*
Total Solids	5,139.0	9,550.0	4,411.0
Calcic Sulfate	1,860.2	2,750.4	890.2
Magnesic Sulfate	1,238.5	2,473.5	1,235.0
Sodic Sulfate	698.9	3,129.7	1,430.8
Sodic Carbonate	421.4	515.7	94.3
Sodic Chlorid	560.2	916.8	357.6
Organic Matter, etc.	360.8	763.9	403.1
Total	5,139.0	9,550.0	4,411.0

§ 62. This table is probably too conservative, but it serves to show that in this soil the solution of sodic and magnesic sulfates takes place in a far greater degree than does that of the other salts. The amount of potassic oxid held in solution or involved in the changes produced by irrigation does not seem to be very significant. The average amount of potassic oxid extracted from this soil by a five days' digestion with dilute hydrochloric acid, 1.115 specific gravity, is 1.25 per cent., or in an acre-foot of soil, taking its weight as 3,500,000, we have 43,750 pounds and the total potassic oxid in this soil is about 2.25 per cent., or 78,750 pounds per acre. I have pointed out elsewhere that there is an abundance of felspar in this soil and also that dilute hydrochloric acid acts very perceptibly upon it, as do also water and carbonic acid. The amount of potassic oxid contained in the ground water before irrigation amounted to 16.6 pounds in each eight inches of water per acre, and after irrigation, 31.7 pounds, an increase of 91 per cent., or 15.1 pounds. This quantity is apparantly not very significant either as an absolute quantity or in comparison with that soluble in dilute hydrochloric acid but there is a view in which it may be significant. A crop of beets of 14 tons to the acre would at maturity contain about 120 or 125 pounds of potassic oxid, or including the tops, 240 to 250 pounds. This represents the season's gathering by the plants, but the application of eight inches of water has in three days involved an eighth of the quantity used by the roots, and one-sixteenth of that used by the whole crop in changes whereby it has passed into solution in the ground water; it may be a case of simple solution, or the solution may have been preceded by other chemical changes, which seems exceedingly probable.

§ 63. In 1899 we had a very much better supply of water which we obtained through the kindness of Water Commissioner C. C. Hawley; this was water taken from the Poudre but it was impossible to prevent the inter-mixing of some seepage water of which we shall give as full an account as is required without endeavoring to give too many details. The facts concerning these waters will appear from the analyses with sufficient fullness and further explanations would be tedious to the reader.

TABLE XXII.—WATER USED IN IRRIGATING, SEPT. 1, 1899.

Analytical Results.	Per Cent.	Grs. Imp. Gal.
Silcic Acid	3.172	0.729
Sulfuric Acid	28.578	6.559
Carbonic Acid	14.493	3.332
Chlorin	3.221	0.741
Sodic Oxid	17.371	3.995
Potassic Oxid	1.298	0.299
Calcic Oxid	18.172	4.180
Magnesic Oxid	5.597	1.287
Ferric and Al. Oxids	0.318	0.073
Manganic Oxid	0.259	0.060
Ignition	8.205	1.887
Sum	100.624	23.142
Oxygen Eq. to Cl.	0.726	0.167
Total	99.898	22.975

Combined.	Per Cent.	Grs. Imp. Gal.
Calcic Sulfate	44.112	10.146
Magnesic Sulfate	3.866	0.889
Magnesic Chlorid	4.312	0.992
Magnesic Carbonate	5.230	1.203
Potassic Carbonate	1.904	0.438
Sodic Carbonate	26.881	6.183
Sodic Silicate	3.227	0.742
Ferric and Al. Oxids	0.318	0.073
Manganic Oxid	0.259	0.060
Ignition	8.205	1.887
Sum	98.314	22.613
Excess Silicic Acid	1.583	0.364
Total	99.897	22.977

Total solids, 23.0 grains per imperial gallon.

TABLE XXIII.— SEEPAGE WATER FROM MERCER DITCH USED IN IRRIGATING, SEPT. 2, 1899.

Analytical Results.	Per Cent.	Grs. Imp. Gal.
Silicic Acid	1.971	0.976
Sulfuric Acid	35.945	17.793
Carbonic Acid	10.989	5.440
Chlorin	3.381	1.674
Sodic Oxid	18.296	9.056
Potassic Oxid	0.641	0.317
Calcic Oxid	17.804	8.813
Magnesic Oxid	5.733	2.838
Ferric and Al. Oxids	0.478	0.236
Manganic Oxid	0.159	0.079
Ignition	5.322	2.634
Sum	100.719	49.856
Oxygen Eq. to Cl.	0.762	0.377
Total	99.957	49.479

Combined.	Per Cent.	Grs. Imp. Gal.
Calcic Sulfate	43.219	21.393
Magnesic Sulfate	15.793	7.818
Magnesic Chlorid	1.114	0.551
Potassic Chlorid	1.014	0.502
Sodic Chlorid	3.411	1.688
Sodic Carbonate	26.498	13.117
Sodic Silicate	19.923	0.952
Ferric and Al. Oxids	0.478	0.236
Manganic Oxid	0.159	0.079
Ignition	5.322	2.634
Sum	98.931	48.970
Excess Silicic Acid	1.024	0.507
Total	99.955	49.477

Total solids, 49.5 grains per imperial gallon.

TABLE XXIV—OFF-FLOW, N. SIDE SEPT. 2, 1899; 1st SAMPLE. *

Analytical Results.	Per Cent	Grs. Imp. Gal.
Silicic Acid	0.688	0.597
Sulfuric Acid	42.183	36.615
Carbonic Acid	6.432	5.583
Chlorin	3.755	3.259
Sodic Oxid	17.140	14.878
Potassic Oxid	1.118	0.970
Calcic Oxid	14.998	13.018
Magnesic Oxid	7.418	6.439
Ferric and Al. Oxids	0.050	0.043
Manganic Oxid	0.050	0.043
Ignition	6.981	6.060
Sum	100.813	87.505
Oxygen Eq. to Cl.	0.846	0.734
Total	99.967	86.771

Combined.	Per Cent.	Grs. Imp. Gal.
Calcic Sulfate	36.408	31.602
Magnesic Sulfate	22.259	19.321
Potassic Sulfate	2.059	1.787
Sodic Sulfate	8.862	7.692
Sodic Chlorid	6.197	5.379
Sodic Carbonate	15.509	13.462
Sodic Silicate	1.397	1.212
Ferric and Al. Oxids	0.050	0.043
Manganic Oxid	0.050	0.043
Ignition	6.981	6.060
Sum	99.772	86.601
Excess Sodic Oxid	0.194	0.168
Total	99.966	86.769

Total solids, 86.8 grains per imperial gallon.

* Sample taken at beginning of off-flow; on-flowing water was ditch water.

TABLE XXV.—OFF-FLOW E. END, SEPT. 2, 1899; 1st SAMPLE. *

Analytical Results.	Per Cent.	Grs. Imp. Gal.	Combined	Per Cent.	Grs. Imp. Gal.
Silicic Acid	2.056	0.977	Calcic Sulfate	45.251	21.494
Sulfuric Acid	32.472	15.424	Magnesic Sulfate	8.792	4.176
Carbonic Acid	14.188	6.738	Magnesic Chlorid	3.835	1.827
Chlorin	2.865	1.361	Magnesic Carbonate	3.294	1.565
Sodic Oxid	18.675	8.871	Potassic Carbonate	1.160	0.551
Potassic Oxid	0.791	0.376	Sodic Carbonate	29.162	13.852
Calcic Oxid	18.641	8.854	Sodic Silicate	3.166	1.504
Magnesic Oxid	6.116	2.905	Ferric and Al. Oxids	0.039	0.017
Ferric and Al. Oxids	0.039	0.077	Manganic Oxid	0.010	0.005
Manganic Oxid	0.010	0.005	Ignition	5.069	2.408
Ignition	5.069	2.408	Sum	99.778	47.399
Sum	100 922	47.936	Excess Silicic Acid	0.497	0.236
Oxygen Eq. to Cl.	0.646	0.307	Total	100.275	47.635
Total	100.276	47.629			

Total solids, 47.5 grains per imperial gallon.
* Sample taken from the first portion of off-flow after running the full length of the plot, 600 feet.

TABLE XXVI.—OFF-FLOW N. SIDE SEPT. 2, 1899; 2nd SAMPLE. *

Analtical Results.	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid	2.069	0.761	Calcic Sulfate	46.511	17.116
Sulfuric Acid	32.676	12 025	Magnesic Sulfate	7.986	2.939
Carbonic Acid	14.379	5.291	Magnesic Chlorid	3.451	1.270
Chlorin	2 578	0.949	Magnesic Carbonate	3.317	1.221
Sodic Oxid	18.247	6 715	Potassic Carbonate	0.951	0.350
Potassic Oxid	0.648	0.238	Sodic Carbonate	29.753	10.949
Calcic Oxid	19.160	7.051	Sodic Silicate	1.641	0 604
Magnesic Oxid	5.696	2.096	Ferric and Al. Oxids	0.010	0 004
Ferric and Al. Oxids	0.010	0.004	Manganic Oxid	0.060	0.022
Manganic Oxid	0.060	0.022	Ignition	5.076	1 868
Ignition	5 076	1.868	Sum	98.756	36.343
Sum	100 599	37.020	Excess Silicic Acid	1.261	0 464
Oxygen Eq. to Cl.	0 581	0.214	Total	100.017	36.807
Total	100 018	36 806			

Total solids, 36.8 grains per imperial gallon.
* Sample taken just before on-flow was cut off.

TABLE XXVII.—OFF-FLOW E. END, SEPT. 2, 1899, 2nd. SAMPLE.*

Analytical Results	Per Cent	Grs. Imp. Gal.	Combined.	Per Cent	Grs. Imp. Gal.
Silicic Acid	2.725	1.150	Calcic Sulfate	41.989	17.719
Sulfuric Acid	34.007	14.351	Magnesic Sulfate	14.588	6.156.
Carbonic Acid	12.588	5.312	Magnesic Chlorid	2.296	0.969
Chlorin	3.029	1.278	Potassic Chlorid	1.290	0.544
Sodic Oxid	18.978	8.009	Sodic Chlorid	1.157	0.488
Potassic Oxid	0.815	0.344	Sodic Carbonate	30.353	12.809
Calcic Oxid	17.709	7.473	Sodic Silicate	1.184	0.499
Magnesic Oxid	5.829	2.460	Ferric and Al. Oxids	0.316	0.133
Ferric and Al. Oxids	0.316	0.133	Manganic Oxid	0.010	0.004
Manganic Oxid	0.010	0.004	Ignition	5.116	2.159
Ignition	5.116	2.159	Sum	98.299	41.480
Sum	101.124	42.673	Excess Silicic Acid	2.142	0.904
Oxygen Eq. to Cl.	0.682	0.288	Total	100.441	42.384
Total	100.440	42.385			

Total solids, 42.2 grains per imperial gallon.
* Sample taken just before on-flow was cut off.

TABLE XXVIII.—ANALYSIS OF WELL D, AUGUST 31, 1899. *

Analtical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.743	1.119	Calcic Sulfate	35.410	22.733
Sulfuric Acid	38 907	24 978	Magnesic Sulfate	23.339	14.984
Carbonic Acid	9.398	6.034	Potassic Sulfate	0.261	0.168
Chlorin	3.968	2.547	Sodic Sulfate	4.269	2 741
Sodic Oxid	19.144	12.290	Sodic Chlorid	6 548	4.204
Potassic Oxid	0.142	0.091	Sodic Carbonate	22.661	14.548
Calcic Oxid	14.587	9.365	Sodic Silicate	1.066	0.684
Magnesic Oxid	7.778	4.993	Ferric and Al. Oxids	0.079	0.051
Ferric and Al. Oxids	0.079	0.051	Manganic Oxid	0.159	0.102
Manganic Oxid	0.159	0.102	Ignition	5.165	3.316
Ignition	5.165	3.316	Sum	98.957	63.531
Sum	101.070	64.886	Excess Silicic Acid	1.218	0.782
Oxygen Eq. to Cl.	0.892	0.572	Total	100.175	64.313
Total	100.178	64.314			

Total solids 64.2 grains per imperial gallon.
* Before irrigation,

TABLE XXIX.—ANALYSIS OF WELL D, SEPT. 2, 1899.*

Analytical Results	*Per Cent*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent*	*Grs. Imp. Gal.*
Silicic Acid	0.460	1.211	Calcic Sulfate	40.381	106.323
Sulfuric Acid	52.466	138.143	Magnesic Sulfate	27.663	72.837
Carbonic Acid	2.369	6.237	Potassic Sulfate	0.871	2.293
Chlorin	1.904	5.013	Sodic Sulfate	17.540	46.183
Sodic Oxid	13.234	34.845	Sodic Chlorid	3.152	8.299
Potassic Oxid	0.473	1.245	Sodic Carbonate	5.712	10.040
Calcic Oxid	16.635	43.800	Sodic Silicate	0.934	2.459
Magnesic Oxid	9.219	24.274	Ferric and Al. Oxids	0.010	0.026
Ferric and Al. Oxids	0.010	0.026	Manganic Oxid	0.030	0.079
Manganic Oxid	0.030	0.079	Ignition	3.651	9.613
Ignition	3.651	9.613	Sum	99.944	263.152
Sum	100.451	264.486	Excess Sodic Oxid	0.074	0.198
Oxygen Eq. to Cl.	0.429	1.129	Total	100.018	263.347
Total	100.022	263.357			

Total solids 263.3 grains per imperial gallon.
*After irrigation.

TABLE XXX.—ANALYSIS OF WELL C, AUG. 31, 1899. *

Analtical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.663	1.369	Calcic Sulfate	34.075	28.044
Sulfuric Acid	40.327	33.189	Magnesic Sulfate	20.122	16.560
Carbonic Acid	7.788	6.410	Potassic Sulfate	0.122	0.100
Chlorin	1.557	1.281	Sodic Sulfate	12.107	9.964
Sodic Oxid	18.846	15.510	Sodic Chlorid	2.569	2.114
Potassic Oxid	0.066	0.054	Sodic Carbonate	18.775	15.452
Calcic Oxid	14.037	11.552	Sodic Silicate	2.368	1.949
Magnesic Oxid	6.706	5.519	Ferric and Al. Oxids	0.090	0.074
Ferric and Al. Oxids	0.090	0.074	Manganic Oxid	0.040	0.033
Manganic Oxid	0.040	0.033	Ignition	8.931	7.350
Ignition	8.931	7.350	Sum	99.199	81.640
Sum	100.051	82.341	Excess Silicic Acid	0.497	0.409
Oxygen Eq. to Cl.	0.350	0.288	Total	99.696	82.049
Total	99.701	82.053			

Total solids 82.3 grains per imperial gallon.
* Before irrigation.

TABLE XXXI.—ANALYSIS OF WELL C. SEPT. 2, 1899. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.397	1.366
Sulfuric Acid	47.826	164.617
Carbonic Acid	2.065	7.108
Chlorin	6.483	22.314
Sodic Oxid,	21.438	73.790
Potassic Oxid	0.197	0.678
Calcic Oxid	10.527	36.234
Magnesic Oxid	8.472	29.161
Ferric and Al. Oxids	0.030	0.103
Manganic Oxid	0.060	0.206
Ignition	3.842	13.224
Sum	101.337	348.801
Oxygen Eq. to Cl.	1.461	5.029
Total	99.876	343.772

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	25.554	87.957
Magnesic Sulfate	25.422	87.503
Potassic Sulfate	0.363	1.249
Sodic Sulfate	27.848	95.853
Sodic Chlorid	10.698	36.823
Sodic Carbonate	4.979	17.138
Sodic Silicate	0.806	2.774
Ferric and Al. Oxids	0.030	0.103
Manganic Oxid	0.060	0.206
Ignition	3.842	13.224
Sum	99.602	342.830
Excess Sodic Oxid	0.272	0.936
Total	99.874	343.766

Total solids, 344.2 grains per imperial gallon.
*After irrigation.

TABLE XXXII.—ANALYSIS OF WELL B, AUGUST 31, 1899. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.838	2.474
Sulfuric Acid	42.859	57.688
Carbonic Acid	5.866	7.896
Chlorin	4.790	6.447
Sodic Oxid	19.527	26.283
Potassic Oxid	0.206	0.277
Calcic Oxid	14.082	18.954
Magnesic Oxid	7.193	9.682
Ferric and Al. Oxids	0.138	0.186
Manganic Oxid	0.069	0.093
Ignition	4.691	6.314
Sum	101.259	136.294
Oxygen Eq. to Cl.	1.079	1.452
Total	100.180	134.842

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	34.184	46.012
Magnesic Sulfate	21.584	29.052
Potassic Sulfate	0.379	0.510
Sodic Sulfate	14.552	19.587
Sodic Chlorid	7.904	10.639
Sodic Carbonate	14.144	19.038
Sodic Silicate	1.369	1.842
Ferric and Al. Oxids	0.138	0.186
Manganic Oxid	0.069	0.093
Ignition	4.691	6.314
Sum	99.014	133.273
Excess Silicic Acid	1.164	1.567
Total	100.178	134.840

Total solids 134.6 grains per imperial gallon.
* Before irrigation.

TABLE XXXIII.—ANALYSIS OF WELL B, SEPT. 2, 1899. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.048	1.555
Sulfuric Acid	43.021	63.843
Carbonic Acid	6.358	9.435
Chlorin	4.286	6.360
Sodic Oxid	19.261	28.583
Potassic Oxid	0.067	0.099
Calcic Oxid	14.454	21.450
Magnesic Oxid	7.131	10.582
Ferric and Al. Oxids	0.020	0.030
Manganic Oxid	0.040	0.059
Ignition	5.381	7.985
Sum	101.067	149.981
Oxygen Eq. to Cl.	0.966	1.433
Total	100.101	148.548

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	35.087	52.069
Magnesic Sulfate	21.398	31.755
Potassic Sulfate	0.123	0.183
Sodic Sulfate	14.221	21.104
Sodic Chlorid	7.073	10.496
Sodic Carbonate	15.331	22.751
Sodic Silicate	0.745	1.106
Ferric and Al. Oxids	0.020	0.030
Manganic Oxid	0.040	0.059
Ignition	5.381	7.985
Sum	99.419	147.538
Excess Silicic Acid	0.681	1.011
Total	100.100	148.549

Total solids, 148.4 grains per imperial gallon.
* After irrigation.

TABLE XXXIV.—ANALYSIS OF WELL A, AUG. 31, 1899. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.370	1.586	Calcic Sulfate	30.416	35.191
Sulfuric Acid	43.578	50.420	Magnesic Sulfate	27.369	31.666
Carbonic Acid	3.838	4.441	Potassic Sulfate	0.342	0.396
Chlorin	5.755	6.658	Sodic Sulfate	12.941	14.973
Sodic Oxid	17.006	19.676	Sodic Chlorid	9.497	10.988
Potassic Oxid	0.186	0.215	Sodic Carbonate	9.255	10.708
Calcic Oxid	12.530	14.497	Sodic Silicate	1.763	2.040
Magnesic Oxid	9.121	10.553	Ferric and Al. Oxids	0.110	0.127
Ferric and Al. Oxids	0.110	0.127	Manganic Oxid	0.060	0.069
Manganic Oxid	0.060	0.069	Ignition	7.751	8.967
Ignition	7.751	8.967	Sum	99.504	115.125
Sum	101.305	117.209	Excess Silicic Acid	0.502	0.581
Oxygen Eq. to Cl.	1.297	1.501	Total	100.006	115.706
Total	100.008	115.708			

Total solids 115.7 grains per imperial gallon.
*Before irrigation.

TABLE XXXV.—ANALYSIS OF WELL A, SEPT. 2, 1899. *

Analytical Results	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.907	1.486	Calcic Sulfate	32.552	53.320
Sulfuric Acid	45.097	73.869	Magnesic Sulfate	27.354	44.806
Carbonic Acid	4.720	7.731	Potassic Sulfate	0.175	0.287
Chlorin	4.621	7.569	Sodic Sulfate	13.546	22.188
Sodic Oxid	16.900	27.672	Sodic Chlorid	7.626	12.491
Potassic Oxid	0.095	0.156	Sodic Carbonate	11.381	18.642
Calcic Oxid	13.407	21.964	Sodic Silicate	0.552	0.914
Magnesic Oxid	9.116	14.932	Ferric and Al. Oxids	0.040	0.065
Ferric and Al. Oxids	0.040	0.065	Manganic Oxid	0.030	0.049
Manganic Oxid	0.030	0.049	Ignition	5.999	9.826
Ignition	5.999	9.826	Sum	99.255	162.588
Sum	100.932	165.329	Excess Silicic Acid	0.635	1.040
Oxygen Eq. to Cl.	1.041	1.705	Total	99.890	163.628
Total	99.891	163.624			

Total solids 163.8 grains per imperial gallon.
*After irrigation.

SANITARY ANALYSES OF IRRIGATION WATERS, AUGUST 31 TO SEPTEMBER 2, 1899.

1. Ditch water as it flowed onto the plot. Sept. 1, 1899.
2. Seepage water as it flowed onto the plot.
3. Water as it flowed off at north side of plot. Sept. 2, 1899. Beginning of off-flow.
4. Water as it flowed off at east end of plot. Sept. 2, 1899. Beginning of off-flow.
5. Water as it flowed off at north side of plot. End of off-flow.
6. Water as it flowed off at east end of plot. End of off-flow.
7. Water of well A. August 31, 1899. Before irrigation.
8. Water of well B. August 31, 1899. Before irrigation.
9. Water of well C. August 31, 1899. Before irrigation.
10. Water of well D. August 31, 1899. Before irrigation.
11. Water of well A. September 2, 1899. After irrigation.
12. Water of well B. September 2, 1899. After irrigation.
13. Water of well C. September 2, 1899. After irrigation.
14. Water of well D. September 2, 1899. After irrigation.

SANITARY ANALYSES OF WATER BEFORE AND AFTER IRRIGATION.

PARTS PER MILLION.

	Total Solids	Chlorin	Nitrates		Nitrites		Ammonia		Albuminoidal Ammonia		Oxygen Consumed
			Nitrogen	Nitric Acid	Nitrogen	Nitrous Acid	Nitrogen	Ammonia	Nitrogen	Ammonia	
1	328.5	9.40	Trace	Trace	0.4400	1.6730	0.3180	0.3860	0.3380	0.4100	4.625
2	707.1	15.30	Trace	Trace	0.0700	0.2340	0.1820	0.2210	0.3140	0.3825	4.450
3	1240.0	50.70	0.440	1.970	0.1400	0.4690	0.3160	0.3840	0.5540	0.6720	7.740
4	678 5	27.10	0.240	1.077	0.2600	0.8700	0.0560	0.0680	0.2490	0.3020	3.875
5	525.7	17.10	Trace	Trace	0.1100	0.3680	0.0630	0.0765	0.3540	0.4290	4.555
6	602.8	18.70	0.080	0.359	0.1000	0.3348	0.0840	0.1020	0.3420	0.4150	5.720
7	1652.8	76.80	0.440	1.970	0.0025	0.0088	0.0320	0.0388	0.2500	0.3029	
8	1922.8	99.50	0.480	2.154	0.0003	0.0010	0.0190	0.0230	0.0950	0.1147	
9	1175.8	57.40	0.560	2.513	0.0025	0.0084	0.0220	0.0267	0.0560	0.0674	
10	917.1	43.10	0 600	2.692	0.0250	0.0837	0.0700	0.0850	0.0860	0.1038	
11	2340.0	108.10	0.720	3.231	0.0025	0.0084	0.0470	0.0570	0.2260	0.2740	
12	2120.0	103.40	0.440	1.970	0.0060	0.0200	0.0600	0.0738	0.1430	0.1730	
13	4917.1	374.30	1.700	7.628	0.0300	0.1000	0.4760	0.5780	2.5680	3.1170	
14	3761.4	107.70	0.360	1.605	0.0900	0.1090	0.4120	0.5000	2.3000	2.7920	

§ 64. We had, as already stated, a good supply of water and can therefore make our calculations on the basis of an acre-foot and approximate closely to the results actually produced. As it was impossible to determine with any approach to accuracy the amount of seepage water which got mixed with the ditch water before it reached the plot, I will neglect it in our estimate but will state separately the amount of salts carried by the seepage as we collected it. The results so far as the amount and character of the salts in the ground water will not be affected thereby.

§ 65. The ditch water carried total solids to the amount of more than twice as much as I have ever found in Poudre water at, or rather a little below, the point where this water was taken out. But I have already pointed out the fact that the Poudre water increases materially in the amount of total solids held in solution from a point just above the mouth of the North Fork to a point below Bellvue, a distance of less than eight miles. The maximum increase observed at a period of low water was about four times the amount contained at the higher point. It is not a matter of surprise then that there should be still greater increase after it has flowed through a cultivated section, for a little more than four miles. This water carried 894.5 pounds of total solids in each acre-foot and the salts represented were not present in the proportions usually found. They were calcic sulfate, 393.6; magnesic sulfate, very little or none; sodic carbonate 239.6 and potassic oxid (K_2O) 11.6 pounds.

§ 66. An acre-foot of the seepage water as it was gathered at the time, carried 1,925 pounds of total solids, but as we do not know the amount of this water flowing in at the time, we cannot make any correction for it. The relative amount was certainly not as much as one-fourth and the weights of salts subsequently dealt with being large and only approximate at best, the seepage water can justly be neglected. The salts held in solution show clearly that it is properly classed as seepage water though evidently mixed with ditch water which had run over the surface of the meadow along the edge of which our lateral ran. These salts were, according to our manner of combining the analytical results, as follows; calcic sulfate, 828.0; magnesic sulfate, 304.0; sodic carbonate, 511.6; potassic oxid (K_2O) 12.4 pounds per acre-foot.

§ 67. The ground water before and after irrigation carried the following quantities of total solids composed of the salts given herewith:

TOTAL SOLIDS IN GROUND WATER AUG. 31.—SEPT. 2, 1899, PER ACRE-FOOT.

	Before Irrigation.	*After Irrigation.*	*Pounds Gain.*
Total Solids	3,868.0	8,809.0	4,941.0
Calcic Sulfate	1,303.5	2,942.2	1.638.7
Magnesic Sulfate	893.5	2,237.5	1,344.0
Sodic Sulfate	425.5	1,612.0	1,186.5
Sodic Carbonate	543.0	740.0	197.0
Sodic Chlorid	255.3	616.6	361.3
Organic Matter, etc.	447.2	660.7	213.5
Total	3,868.0	8,809.0	4,941.0

§ 68. This shows an increase in the total solids contained in each acre-foot of ground water of 4,941 pounds, but if we con-

sider, as suggested in the observations made on the irrigation of 1898, that the ground water as taken after irrigation represents a mixture of equal parts of irrigation water and ground water we find that to produce this change in the amount of total solids 12,856 pounds of salts must have passed into solution.

§ 69. For the experiment of 1898 we found that 4,411 pounds went into solution or, assuming a mixing to the extent of equal parts, 12,664 pounds per acre-foot; for 1899 we have 4,941 pounds and 12,856. When we attempt to find how this gain was distributed between the different salts we find the same order, namely sodic sulfate, magnesic sulfate and calcic sulfate. In 1899, however, the calcic sulfate shows a greater increase than in 1898. This is accounted for by the influence of well D, which in 1898 could not be included, because being near the point of onflow it was not looked after as carefully as it should have been, and the water getting advantage of us ran into the well from the surface. In 1898 the percentage of calcic sulfate in the residue from the ground water was lower after irrigation than before, except in the case of well D, which showed an increase of five per cent. The result is probably correct and represents what actually took place, but it is contrary to our observations. While it modifies our general results, it does not reverse them.

§ 70. The potassic oxid in an acre-foot of the ditch water used was only 11.6 pounds, in the ground water before irrigation 5.8 pounds, in the ground water after irrigation 18.3 pounds, or if we consider the ground water after irrigation as representing a mixture of equal parts, as before, we have 19.2 pounds of potassic oxid brought into solution by the application of an acre-foot of water.

§ 71. The water that flowed over and off of the plot was not large in quantity but we collected samples as near the beginning and end of off-flow as was feasible. The salient features of the results will be seen upon an examination of the analyses.

§72. The off-flow took place at two points, one near the center of the north side of the plot, the other at the east end, the water flowing from west to east.

§ 73. The samples obtained of the off-flow on the north side showed a very marked difference in the quantity of total solids present in the first and second samples. The first sample contained 3,390, the second 1,431 pounds per acre-foot. The sample taken at the east end of the plot showed the same fact but much less markedly; the first sample containing 1,847, the second 1,641 pounds per acre-foot. This difference is accounted for, I think, by the fact that we failed to get the first portion of the off-flow at the east end, while we succeeded in getting it at the north side. The decrease in the total salts carried in solution by such water is

very rapid at first and gradually becomes slower which fully explains the differences observed in these two sets of samples. It is evident from what I have said, relative to the amount of off-flow and the fact that it was only by the courtesy of the water commissioner that we obtained this water, that we did all that we could with this subject. When we consider that this water on leaving the plot after flowing over it for 600 feet had only washed off and dissolved out between 800 and 1,000 pounds of salts per acre-foot, under very favorable conditions, and that the rate of action decreases rapidly it would seem to indicate that long continued flooding with off-flow would not be an advisable proceedure in order to remove salts from the soil.

§ 74. There is one thing suggested by the analyses, i. e., that in the case of long continued flooding the amount of potash removed might become a matter worthy of consideration. The percentage of this substance present in the residue from the off-flowing waters is not so high as in the residue obtained from the waters applied, but when the increase in the total solids is taken into consideration it indicates a probable loss of this substance. Our data is not adequate to justify general conclusions on this subject. My opinion, however, is that the loss is less serious than one would be inclined to think, judging from the results shown by these samples.

§ 75. The sanitary analyses show the same facts relative to the total solids and chlorin, but they are given in terms of parts per million, instead of grains per gallon. In the total solids we discover an extreme quantity in the well waters after irrigation, equal to 13 times the quantity in the water used for irrigating, and over four times the amount found in the same well before irrigation. The chlorin is 40 times greater in the well water after irrigation than in the ditch water applied, and between six and seven times greater than in the same well before irrigation. The principal object in making the sanitary analyses was to determine the different forms and quantities in which nitrogen was present. The quantities found, even when taken together, are scarcely worth considering so far as their fertilizing value is concerned. The ditch water used in 1899 contained in all forms almost three pounds of nitrogen per acre-foot. The soil to which this water was applied contained in the first foot of soil 3,500 pounds. The three pounds of nitrogen, if it were present as potassic nitrate, would be insignificant, but the analysis shows that none of it was present as nitric acid. This ditch water shows the presence of more nitrous acid than any sample analyzed in connection with the work.

§ 76. The seepage water that mingled with the ditch water was even poorer in nitrogen than the ditch water, so the water

used in this irrigation literally vanishes as a factor in any question pertaining to nitrogen.

§ 77. The nitrates, or rather the corresponding nitric acid in the ground water before and after irrigation, does not show changes on the scale I anticipated. An acre-foot of ground water before irrigation contained 6.413 pounds of nitric acid, as nitrates, and after irrigation 9.861 pounds, which correspond roughly to 2.2 pounds of nitrogen, a wholly insignificant amount from any practical standpoint. The amount is not only small but it must also be considered that at least three and one-half feet of soil have probably been involved in producing this result. Whatever reactions may have taken place, the elimination, or the passing of the nitrates into a free solution, has taken place to a very small extent.

§ 78. Nitrous acid is present, both before and after irrigation, in such small quantities that a much more extended and careful investigation would be required to justify even a tentative interpretation. The quantity present after, is greater than before irrigation, but the quantity present in either case is small, not a tenth of that present in the ditch water.

§ 79. In the spring of 1900 we had an exceptionally heavy precipitation, snow and rain. Beginning March 27, we had 3.5 inches of snow; on the 30th, a little rain, and from April 4 to 9 inclusive, rain or snow daily. During this time we had 12 inches of snow fall, and a total of 4.2 inches of water. This differs materially from an irrigation of 4.2 inches, the whole surface of adjacent land receiving the same amount of water which, I consider, influences the water plane materially, either by movement or pressure. The water plane in this case was brought up to within a few inches of the surface. This may have been the result of water from the adjoining lands. The snow which melted slowly, and to which there was a daily addition of from .2 to .4 inches of rainfall at this time, gave the water opportunity to enter the soil slowly and over the whole area at the same time. Samples of well A were taken April 9 and 17, 1900, when the water plane was perhaps at its highest point, the analysis of which resulted as follows:

TABLE XXXVI.—ANALYSIS OF WELL A, APR. 9, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.271	1.965	Calcic Sulfate	16.733	121.314
Sulfuric Acid	45.332	328.657	Magnesic Sulfate	36.146	262.059
Carbonic Acid	1 383	10.027	Potassic Sulfate	0.291	2.110
Chlorin	8.931	64.749	Sodic Sulfate	19.993	144.949
Sodic Oxid	18.936	137.286	Sodic Chlorid	14.738	106.850
Potassic Oxid	0.158	1.146	Sodic Carbonate	3.335	24.179
Calcic Oxid	6 893	49.974	Sodic Silicate	0.550	3.987
Magnesic Oxid	12.046	87.333	Ferric and Al. Oxids	0.050	0.363
Ferric and Al. Oxids	0.050	0.363	Manganic Oxid	0.060	0.435
Manganic Oxid	0.060	0.435	Ignition	8.206	59.493
Ignition	8.206	59.493	Sum	100.102	725.739
Sum	102.266	741.428	Excess Sodic Oxid	0.148	1.073
Oxygen Eq. to Cl.	2.012	14 587	Total	100.250	726.812
Total	100.254	726.841			

Total solids 725.0 grains per imperial gallon.

TABLE XXXVII.—ANALYSIS OF WELL A, APRIL 17, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.284	1 285	Calcic Sulfate	16.832	76.131
Sulfuric Acid	45.565	206.090	Magnesic Sulfate	33.716	152.497
Carbonic Acid	2.347	10.615	Potassic Sulfate	0.160	0.724
Chlorin	7.554	34.167	Sodic Sulfate	23.286	105.323
Sodic Oxid	20.108	90 948	Sodic Chlorid	12.466	56.384
Potassic Oxid	0.087	0.394	Sodic Carbonate	5.659	25.596
Calcic Oxid	6.934	31.362	Sodic Silicate	0.016	0.072
Magnesic Oxid	11.236	50.820	Ferric and Al. Oxids	0.030	0.136
Ferric and Al. Oxids	0.030	0.136	Manganic Oxid	0 030	0.136
Manganic Oxid	0 030	0.136	Ignition	7.618	34.456
Ignition	7 618	34.456	Sum	99.813	451 455
Sum	101.793	460.409	Excess Silicic Acid	0.276	1.248
Oxygen Eq. to Cl.	1.702	7.698	Total	100.089	452.703
Total	100.091	452.711			

Total solids 452.3 grains per imperial gallon.

TABLE XXXVIII.—ANALYSIS OF WELL G, APRIL 17, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.285	1.340	Calcic Sulfate	24.535	115.364
Sulfuric Acid	44 885	211.049	Magnesic Sulfate	29.200	137 298
Carbonic Acid	1.964	9.235	Potassic Sulfate	0.655	3.080
Chlorin	8.216	38 632	Sodic Sulfate	18 980	89.244
Sodic Oxid	18.741	88.120	Sodic Chlorid	13.558	63.750
Potassic Oxid	0.359	1 688	Sodic Carbonate	4.736	22.268
Calcic Oxid	10.107	47.523	Sodic Silicate	0.579	2.722
Magnesic Oxid	9 731	45 755	Ferric and Al. Oxids	0.040	0.188
Ferric and Al. Oxids	0 040	0.188	Manganic Oxid	0.010	0 047
Manganic Oxid	0 010	0 047	Ignition	7.534	35.425
Ignition	7 534	35.425	Sum	99.827	469.386
Sum	101 872	479.002	Excess Sodic Oxid	0.192	0.903
Oxygen Eq. to Cl.	1.851	8.703	Total	100.019	470.289
Total	100.021	470.299			

Total solids 470.2 grains per imperial gallon.

§ 80. The sample of water taken April 9, 1900, well A, just before the end of an unusually heavy and protracted rainfall, whereby the ground was filled with water, contains in an acre-foot of water 28,197 pounds of salts. The water of this well is usually high, therefore to obtain a better idea of what the actual increase is, I have computed the average amounts of sulfates in this water as given for 11 samples taken in 1898. When the water was low in this well the total solids were also low. In November, 1898, there were 164 grains per gallon.

WATER OF WELL A.

	April 9, 1900.	*Average for 1898.*
Total solids in an acre-foot	28,197 pounds	8,899 pounds
Calcic Sulfate	4,708 pounds	3,115 pounds
Magnesic Sulfate	10,179 pounds	2,492 pounds
Sodic Sulfate	5,639 pounds	979 pounds

§ 81. The sample of water, well A, taken eight days later, serves to show how rapidly the total solids fell at this time. The water plane had in meantime fallen about 0.8 of a foot. The total solids in an acre-foot have fallen from 28,197 to 17,722 pounds, a difference of about 10,000 pounds. Further, the salts remaining in solution have another ratio. On April 9, the calcic to the magnesic to the sodic sulfate stood roughly as 1 : 2 : 1, but on the 17th inst. they stood as 1 : 5 : 3½, from which it appears that the calcic sulfate has receded to the greatest extent, magnesic sulfate next and the sodic sulfate in the least measure.

§ 82. Well G is near well A but is a shallower well and its waters are separated from those in an underlying stratum of gravel as explained in a former bulletin. This sample perhaps represents the water in the soil more faithfully than does the water of well A, but in the main it presents the same general features, the relative quantity of the salts being a little different and their total quantity a little higher.

§ 83. Other samples of water were taken from these wells one month later, when the water plane had fallen 16 inches. These samples show 142.5 grains total solids for well A, a decrease of 582.5 grains; and 379 for well G, a decrease of 91 grains per gallon. The percentage of calcic sulfate had materially increased in well A, but only slightly in G; that of the magnesic sulfate was about the same, while the percentage of sodic sulfate had decreased in each case.

§ 84. We have more potassic oxid in the water from well G than in that from well A. In the latter we have 44.5 pounds, in the former 63.6 pounds per acre-foot, neither of them being very large quantities; the smaller being scarcely 10 times as much as water dissolves from finely divided felspar in a few days.

§ 85. These experiments indicate that either simple solution of salts, feebly held in the soil, takes place on a large scale, or else

a series of reactions whereby these salts pass into solution when the soil is supplied with an abundant quantity of water; but the relative quantities that go into solution vary, and the ratios in which the salts are present are not those of their solubilities.

THE DRAIN WATERS.

§ 86. There was no drain through the plot of ground at the time the irrigation experiments were made, so I can not give analyses of drain waters which are strictly comparable to the waters used in irrigation. I regret this but I could not do better than to take drain water from another point, which I did. This plot was subsequently drained and an analysis of the water from this drain will be given later. The first sample of drain water which I shall give was taken April 20, 1900, three days later than the last sample of well water given, and is fairly comparable to these, though taken at some distance below the plot where the wells were dug.

TABLE XXXIX.—ANALYSIS OF DRAIN WATER, APR. 20, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.846	0.963	Calcic Sulfate	40.406	45,982
Sulfuric Acid	40.284	45.843	Magnesic Sulfate	21.260	24.194
Carbonic Acid	8.537	9.715	Potassic Sulfate	0 145	0.165
Chlorin	3.939	4.483	Sodic Sulfate	4.052	4.611
Sodic Oxid	17.304	19.692	Sodic Chlorid	6.500	7 397
Potassic Oxid	0.079	0.090	Sodic Carbonate	20 585	23.426
Calcic Oxid	16.645	18.941	Sodic Silicate	0.071	0 081
Magnesic Oxid	7.085	8.063	Ferric and Alu. Oxids	0.050	0.057
Ferric and Al. Oxids	0.050	0.057	Manganic Oxid	0 060	0.068
Manganic Oxid	0.060	0.068	Ignition	6.379	7.259
Ignition	6.379	7.259	Sum	99.508	113.240
Sum	101.208	115.174	Excess Silicic Acid	0.811	0.923
Oxygen Eq. to Cl.	0.887	1.009	Total	100.319	114.163
Total	100.321	114.165			

Total solids, 113.8 grains per imperial gallon.

§ 87. This sample was taken from a new drain which was being laid beside an old one. The gravel at this time was full of water as is, so far as I know, always the case. This is the same stratum of gravel mentioned in another place, also in former bulletins, as underlying my beet plot. A comparison of the preceding analysis with one of water taken from this gravel under the beet plot, shows a general similarity, but with some differences, the most striking of which is in regard to the sodic sulfate, which is much more abundant in the water taken directly from the gravel than in the drain water. In this connection I would repeat what I have said in Bulletin No. 72, page 33, that the ground and drain waters are not alike; that the total solids decrease with the depth from which the sample is taken, and that while sodic sulfate is abundant in the ground waters, it is not so

in the drain waters. We have in this case an illustration in point. The ground waters taken three days previously showed the presence of 452 and 470 grains total solids per imperial gallon; the above drain water showed 113.8 grains. The ground waters showed respectively 105 and 89 grains of sodic sulfate per gallon, the drain water 4.6 grains, which in proportion is very greatly less, the sodic sulfate amounting to one-fourth of the total in the case of ground water, represented by well A, and 1-24 in that of the drain water; the magnesic sulfate remaining relatively constant, one-third in the well waters and one-fifth in the drain water. The calcic sulfate, on the contrary constitutes 1-6 and 1-5 respectively of the total solids in the two well waters and 2-5 of those in the drain water. I unfortunately do not know even approximately the volume of drainage water, but it is evident that the ratios in which the various salts are removed are wholly different from these in which they are found in the ground water.

§ 88. The following analyses of drain waters establish and strengthen these statements and show that the drain waters are much more nearly constant in composition than the ground waters, and vary much less in the quantity of total solids that they contain.

TABLE XL—ANALYSIS OF DRAIN WATER, JULY 23. 1900.

Analytical Results	*Per Cent*	*Grs. Imp. Gal.*
Silicic Acid	1.405	1.030
Sulfuric Acid	42.442	31.110
Carbonic Acid	7.847	5.752
Chlorin	3.782	2.772
Sodic Oxid	14.663	10.748
Potassic Oxid	0.115	0.084
Calcic Oxid	18.647	13.668
Magnesic Oxid	7.876	5.773
Ferric and Al. Oxids	0.040	0.029
Manganic Oxid	0.040	0.029
Ignition	4.073	2.985
Sum	100.930	73.980
Oxygen Eq. to Cl.	0.852	0.624
Total	100.078	73.356

Combined.	*Per Cent*	*Grs. Imp. Gal.*
Calcic Sulfate	45.265	33.179
Magnesic Sulfate	23.633	17.323
Potassic Sulfate	0.147	0.108
Potassic Chlorid	0.055	0.040
Sodic Chlorid	6.198	4.543
Sodic Carbonate	18.921	13.869
Sodic Silicate	0.589	0.432
Ferric and Al. Oxids	0.040	0.029
Manganic Oxid	0.040	0.029
Ignition	4.073	2.985
Sum	98.961	72.537
Excess Silicic Acid	1.115	0.817
Total	100.076	73.354

Total Solids, 73.3 grains per imperial gallon.

TABLE XLI.—ANALYSIS OF DRAIN WATER, MRS. CALLOWAY'S RANCH, JULY 23, 1900.

Analytical Results.	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid	1.425	0.886	Calcic Sulfate	44.734	27.824
Sulfuric Acid	40.202	25.006	Magnesic Sulfate	18.013	11.204
Carbonic Acid	9.549	5.939	Potassic Sulfate	0.212	0.132
Chlorin	3.635	2.261	Sodic Sulfate	3.177	1.976
Sodic Oxid	18.070	11.239	Sodic Chlorid	5.998	3.731
Potassic Oxid	0.115	0.072	Sodic Carbonate	23.025	14.322
Calcic Oxid	18.428	11.462	Sodic Silicate	0.047	0.029
Magnesic Oxid	6.003	3.734	Ferric and Al. Oxids	0.050	0.031
Ferric and Al. Oxids	0.050	0.031	Manganic Oxid	0.080	0.050
Manganic Oxid	0.080	0.050	Ignition	3.405	2.118
Ignition	3.405	2.118	Sum	98.741	61.417
Sum	100.962	62.798	Excess Silicic Acid	1.402	0.872
Oxygen Eq. to Cl.	0.819	0.509	Total	100.143	62.289
Total	100.143	62.289			

Total solids 62.2 grains per imperial gallon.

TABLE XLII—ANALYSIS OF DRAIN WATER, BEET PLOT, FEB. 23, 1903.

Analytical Results.	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid	0.812	1.302	Calcic Sulfate	44.033	70.631
Sulfuric Acid	49.143	78.825	Strontic Sulfate	0.508	0.815
Carbonic Acid	2.955	4.632	Magnesic Sulfate	26.310	42.201
Chlorin	3.545	5.686	Potassic Sulfate	0.353	0.566
Sodic Oxid	12.231	19.618	Sodic Sulfate	9.572	15.354
Potassic Oxid	0.191	0.306	Sodic Chlorid	5.712	9.162
Lithic Oxid	0.033	0.053	Lithic Chlorid	0.092	0.148
Calcic Oxid	18.141	29.098	Sodic Carbonate	7.115	11.371
Strontic Oxid	0.287	0.460	Sodic Silicate	1.646	2.640
Magnesic Oxid	8.822	14.150	Ferric and Al. Oxids	0.075	0.120
Ferric and Al. Oxids	0.075	0.120	Manganic Oxid	0.030	0.048
Manganic Oxid	0.030	0.048	Ignition	4.512	7.237
Ignition	4.512	7.237	Sum	99.988	160.293
Sum	100.777	161.535	Excess	None	None
Oxygen Eq. to Cl.	0.799	1.282	Total	99.988	160.293
Total	99.978	160.253			

Total solids 160.4 grains per imperial gallon.

§ 89. These drain waters present as great a variety as I would probably have obtained had I taken a great number from other localities. I hope and think that they represent such drain waters as we have in this section of Colorado. An examination of them shows that they contain relatively considerably more sodic carbonate than the ground waters, but less potassic salts.

§ 90. The drain on Mrs. Calloway's ranch is 500 feet long, four feet deep at its upper end, nine feet at the lower and has been open for some years. The rainfall during March, April and May of the year 1900 amounted to 13.38 inches, and the sample being taken July 23rd, was taken subsequently to the irrigation, if any were applied, which was probably the case, though I have no specific information on this point. Such were the conditions pre-

ceding the taking of the sample and they also apply to the sample taken from the drain east of the beet plot.

§ 91. The sample taken from the drain underlying the beet plot in 1903 ought to be the nearest representative of the ground waters, analyses of which have been given. This drain was not laid at the time the samples of the ground water were taken. This sample ought to represent the drain water from this plot of ground. There had been but little or no rain for some time, the surface ground was frozen and the sample was taken on this date, Feb. 23, because we feared that a thaw might set in and we would have to wait a long time and perhaps never obtain a more representative drain water than that which we were then able to procure. The presence of strontic and lithic oxids in this analysis is what we would expect from what has been said in connection with the river water. They have been found present whenever tested for, but being of subordinate importance they were not determined in the other samples, the one being included with the lime and the other with the sodic oxid.

§ 92. The potassic oxid found in the ground waters varied from 0.01 of one per cent. of the total solids to 1.2 per cent., with an average of 0.262 for the 92 samples averaged; whereas the average for the drain waters is 0.125 per cent., which calculated per acre-foot of water gives 20.7 pounds in the ground water to 5.0 pounds in the drain water. From the point of its fertilizing value, this amount is not very significant, but it serves to show the ratio which exists between the amounts in the ground and drain waters or the extent to which the soil retains the potash, if we may put it that way.

§ 93. In regard to the sodic salts we find a difference between the sulfates and chlorids. Adopting the average percentage of sodic sulfate found in the total solids of well A in 1898, which is probably a little too high to be accurate but will represent the general facts with sufficient accuracy, we find in an acre-foot of the ground water 868 pounds of sodic sulfate, and in a like quantity of drain water 168 pounds, or one-fifth as much. In Bulletin No. 72 I called attention to the fact that the salts in solution fell as the water plane fell, the salts seeming to remain in the soil. I also called attention to the fact that the upper portions of the ground water were richer in total solids than the lower and at the same time contained higher percentages of sodic sulfate. I find in the drain water further proof of what I then observed by taking samples directly from the soil. We see that sodic sulfate does not pass readily into the drain waters. Not only the absolute amount falls, but its relative amount, showing that the soil particles retain it as there suggested.

§ 94. The sodic chlorid deports itself in the same manner. Again, using well A as an example, we have in an acre-foot of its water 925 pounds of sodic chlorid, or common salt, and 240 pounds in an acre-foot of drain water. I have compared other well waters and find this to be the rule. The difference is not necessarily the same but it is always in the same direction. The only time that the percentage of sodic chlorid in the total solids of the ground waters approaches that of those of the drain waters, is when the water plane has fallen quite low, in other words, when it has approached the level of the drain. These statements do not seem to be in perfect harmony with the theory of absorption of salts by different soils, and the fact that, as a rule, there is an excess of bases in the residues left by these waters, rather than acids, as would be required by the theories set forth in our text books, points to the prevalence of conditions entirely different from those under which the classical experiments, upon which our theories are based, were made.

§ 95. Only two of these drain waters were submitted to sanitary analysis, with the following results:

TABLE XLIII.—SANITARY ANALYSES OF DRAIN WATERS

1. Drain water, Mrs. Calloway's ranch, July 23, 1900.
2. Drain east of beet plot, July 23, 1900.

	Total Solids	Chlorin	Nitrates		Nitrites		Ammonia		Albuminoidal Ammonia		Oxygen Consumed
			Nitrogen	Nitric Acid	Nitrogen	Nitrous Acid	Nitrogen	Ammonia	Nitrogen	Ammonia	
1	880 5	40.7	0.240	1.0770	0.1400	0.4690	0.0410	0.0496	0.1000	0.1210	1.3650
2	1047.1	44.3	0.480	2.1540	1.3000	4.3550	0.0720	0.0871	0.1900	0.2299	2.0500

§ 96. I regret that these samples were not taken at the same time that the samples of irrigation water were taken, but they were not, and these will have to serve our purpose in such measure as they may.

§ 97. It will be seen by referring to the table of analyses of irrigation waters that the well waters taken August 31, 1899, before irrigation, were richer in nitric acid than these drain waters, as were also those taken after irrigation; but the drain waters are very much richer in nitrous acid. The ammonia, both saline and albuminoidal, is less in the drain water than in the irrigation and ground waters. The nitric acid removed per acre-foot by the richer of the two drainage waters is but 5.748 pounds. In the course of a year the amount of nitric acid in pounds avoirdupois transported by such waters, in the form of nitrates, is a comparatively large number, but when we attempt to estimate the area from which this is collected and think of the scale on which na-

ture operates, the amount is trifling. An example will show how thoroughly justified is this statement. If our soil contained 0.1 per cent. of nitrogen and we take two acre-feet of it, it will contain in round numbers 7,000 pounds of nitrogen. It would take 1,227 acre-feet of drain water to contain this amount, taking all forms of nitrogen existing in the water. The drain water does not, unfortunately, represent the water draining from any given acre of soil, but that draining from many acres. It is understood that the value of such examples is purely illustrative.

THE RETURN WATERS.

§ 98. We have considered the Poudre water and seen that it suffers little or no change in character so long as it remains in its mountain course, but that its character changes rapidly as it enters the plains. We have seen that in flowing through the ditches for use in direct irrigation it also changes rapidly. (See table XII—analysis of ditch water as used for irrigation). We have studied the effects of storage upon the amount and character of the salts held in solution. (See analysis of waters of Terry lake, Long pond, Warren's and Windsor lakes). We have further endeavored to present the manner and extent that its composition is changed by flowing over the soil as off-flow water; by entering the soil as ground water; by passing through and flowing out of it as drain water.

§ 99. If possessed with the desire to do so, anyone could make suggestions which, had they been feasible at the time, or perhaps even been seen as they can now be seen, would, if followed out, add greatly to the value of this work. From the very beginning I desired to make a study of the changes taking place upon the application of water for irrigation purposes in a different manner, but it was not feasible and I have done the best that I could. While I think the results of my experiments in this regard exaggerate some of the relations of the individual results to one another, I am not prepared to regret the fact, for I believe that the exaggeration serves a good purpose by emphasizing; for instance, the profound manner in which the laws of diffusion are modified within the soil, and the tenacity with which the soil particles retain the molecules of different salts, without in any appreciable way destroying their value, as a presentation of the typical reactions which take place. I think that it is true everywhere under our conditions that calcic sulfate is permitted to pass with comparatively more freedom than sodic sulfate or chlorid. I do not know whether this is due to the presence of this salt in quantities approaching the point of saturation of the soil and water, or not. With whatever weaknesses and insufficiencies our experiments may be beset, we have placed them upon record and will

examine what the results of the bigger practice, i. e., the irrigation of the whole valley may show.

§ 100. I have stated that seepage or return waters begin to enter the river almost immediately upon its leaving the mountains, and have cited the increase in the total solids in the river water between a point above the North Fork and the water works, in support of it. The amount of such water increases as we go down the river.

§ 101. We can present the matter thus: The water of the Poudre is taken from the river, used for irrigation, and after a time returns. The return waters have passed through or flowed over the soil. The amount returning to the river as waste water, is so small that I would not take note of it, even if I had sufficient data to justify me in attempting to do so. But I have not such data. Much of the water appearing in the lower part of the river has doubtlessly been used several times, but I doubt whether its composition is, on this account, any more or less indicative of the effects of the irrigation waters upon the soil, or of changes which take place within the soil, than water which has not been used repeatedly. I am inclined to think that in such cases the composition of the return waters is dependent almost wholly upon the character of the soil from which it last issued. This question is of great importance in interpreting the results of the analysis of return waters. The river bed may be bordered by a margin of low land, as it frequently is, the water draining from the higher land having to pass through this, either in small streams or by the slower method of percolation. In either event there is opportunity for a material modification of the composition of the water. Still, as has already been said, we have in the return waters the result of all the changes, and a measure of the effects produced by irrigating, not a field, but a whole section of country. Our measure is essentially the drain water of all this larger section, and in this case drain water means water that has passed through, not run over, the soil as rain water or as waste water from ditches.

§ 102. In order to save space and bring the analyses of return waters together, I will anticipate a little and introduce the analysis of the Platte river water below the mouth of the Poudre, it being return water, but I shall give those of the Poudre the first place, not only in order, but in importance.

TABLE XLIV.—ANALYSIS OF POUDRE RIVER WATER, SAMPLE TAKEN TWO MILES ABOVE GREELEY, AUGUST 11, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.904	1.035
Sulfuric Acid	48.009	54.970
Carbonic Acid	5.171	5.920
Chlorin	2.419	2 770
Sodic Oxid	12.742	14.590
Potassic Oxid	0.394	0 451
Calcic Oxid	16.540	18.938
Magnesic Oxid	10 646	12.190
Ferric and Al. Oxids	0.069	0.079
Manganic Oxid	Trace	Trace
Ignition	3.660	4 191
Sum	100.554	115.134
Oxygen Eq. to Cl.	0.545	0.634
Total	100.009	114.500

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	40.186	46.013
Magnesic Sulfate	31.796	36.406
Potassic Sulfate	0.628	0.719
Sodic Sulfate	5.292	6.059
Sodic Chlorid	3.987	4.565
Sodic Carbonate	12.469	14.277
Sodic Silicate	1.833	2.099
Ferric and Al. Oxids	0 069	0.079
Manganic Oxid	Trace	Trace
Ignition	3.660	4.191
Sum	99 920	114.408
Excess Sodic Oxid	0 084	0.096
Total	100.004	114.504

Total solids 114.5 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	1,017.140
Chlorin	36.630
Nitrogen as Nitrates	0.400
Nitrogen as Nitrites	0 022

	Parts Per Million.
Saline Ammonia	0 060
Albuminoidal Ammonia	0.160
Oxygen consumed	1.160

TABLE XLV.—ANALYSIS OF POUDRE RIVER WATER, SAMPLE TAKEN THREE MILES EAST OF GREELEY, AUGUST 10, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.336	0.951
Sulfuric Acid	42.660	30.374
Carbonic Acid	7.144	5.087
Chlorin	3.013	2.145
Sodic Oxid	12.819	9.117
Potassic Oxid	0.523	0.372
Calcic Oxid	19.785	14.087
Magnesic Oxid	7.854	5.592
Ferric and Al. Oxids	0.055	0.039
Manganic Oxid	0.110	0.078
Ignition	5.433	3 868
Sum	100.731	71.710
Oxygen Eq. to Cl.	0.679	0.483
Total	100.052	71.227

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	48.068	34.124
Magnesic Sulfate	21.621	15.394
Magnesic Chlorid	1.431	1.019
Potassic Chlorid	0 827	0 589
Sodic Chlorid	2.566	1 827
Sodic Carbonate	17.227	12.266
Sodic Silicate	2.710	1.930
Ferric and Al. Oxids	0.055	0.039
Manganic Oxid	0.110	0.078
Ignition	5.433	3.868
Sum	100.048	71.134
Excess	None	None
Total	100.048	71 134

Total solids, 71.2 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	1,635.710
Chlorin	45.550
Nitrogen as Nitrates	0.300
Nitrogen as Nitrites	0.015

	Parts Per Million.
Saline Ammonia	0.120
Albuminoidal Ammonia	0.180
Oxygen consumed	2.127

TABLE XLVI.—ANALYSIS OF PLATTE RIVER WATER, SAMPLE TAKEN ONE MILE SOUTH AND FOUR EAST OF GREELEY, AUGUST 11, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	1.214	0.891	Calcic Sulfate	43.651	32.040
Sulfuric Acid	44.416	32.601	Magnesic Sulfate	22.504	16.518
Carbonic Acid	6.205	4.554	Potassic Sulfate	0.892	0.655
Chlorin	3.653	2.681	Sodic Sulfate	5.959	4.374
Sodic Oxid	15.617	11.463	Sodic Chlorid	6.028	4.425
Potassic Oxid	0.483	0.355	Sodic Carbonate	14.962	10.982
Calcic Oxid	17.966	13.117	Sodic Silicate	2.087	1.532
Magnesic Oxid	7.535	5.530	Ferric and Al. Oxids	0.257	0.189
Ferric and Al. Oxids	0.257	0.189	Manganic Oxid	0.257	0.189
Manganic Oxid	0.257	0.189	Ignition	3.266	2.397
Ignition	3.266	2.397	Sum	99.863	73.301
Sum	100.869	73.967	Excess Silicic Acid	0.124	0.091
Oxygen Eq. to Cl.	0.823	0.604	Total	99.987	73.392
Total	100.046	73.372			

Total solids, 73.4 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		*Parts Per Million.*
Total Solids	1,048.570	Saline Ammonia	0.020
Chlorin	42.590	Albuminoidal Ammonia	0.150
Nitrogen as Nitrates	0.400	Oxygen consumed	0.994
Nitrogen as Nitrites	0.015		

§ 103. The samples of Poudre water were taken at points at least seven miles apart as the river flows. The water on this date was not only representative of return water, but was wholly such as had come into the river within the last few miles above these points. The water taken at the lower point had, for the greater part, returned within the last seven miles. This fact may account for the differences presented by the analyses. There is no reason for any one to stumble over, or raise any question about, the manner of combining these salts, for the variations which can be shown in this way have no weight in the larger features presented by these results.

§ 104. The three principal salts in these waters are, in the order of their relative quantities, calcic sulfate, magnesic sulfate and sodic carbonate. The sulfate of soda present in such notable quantities in the ground waters, and still more so in nearly all of the efflorescences, is very subordinate or absent. The potassic oxid is present in a slightly higher percentage than the average found for our ground waters, but the total solids is very much less.

§ 105. The sanitary analyses show that in total nitrogen the return waters are not so unlike the ground waters as one would expect, as they resemble those taken before irrigation quite closely. The only exception being the Arkansas river water, taken at Rockyford, in which we found large quantities of both nitrates and nitrites. I know much less about the conditions obtaining in re-

gard to this sample than in the other cases, and it is not feasible for me to gather the facts in this case with the completeness and accuracy that would permit me to make any explanatory statements, therefore I content myself with recording the results of the analysis which is given later.

§ 106. Fortunately the Poudre river was gauged in 1902, a few days before my samples were taken, and we have very excellent data enabling us to calculate the results indicated by our analyses, with the assurance that they are correct within narrow limits. On July 27, the flow at the pump house above Greeley was 24 second-feet, at the mouth of the river it was 29 second-feet. We will use the latter figure in calculating the total work done by the Poudre river as an irrigation stream. This flow delivers nearly 2.4 acre-feet per hour, or 57.6 acre-feet per day. At the pump house the flow amounted almost to 48 acre-feet per day. As the supply of water during the season of 1902 was very short, we may consider the following figures as representing the minimum effect of the stream.

§ 107. With a flow of 57.6 acre-feet daily, it carries a total of 79.75 tons of salts into the Platte river. A like quantity of water, as it flows through the canyon of the Poudre, would contain only 3.25 tons, or a gain of 76.5 tons, but the flow at the mouth of the river is not the same as in the canyon, it being much greater. The following figures will show the total salts carried through the canyon in solution, and will also give an idea of the daily consumption of water taking place between the canyon and the mouth of the river. The weight of the salts carried through the canyon of the Poudre on this date was 32.5 tons. The amount delivered to the Platte was 79.75 tons, a difference of 47.25 tons. This naked statement of end results does not give a fair idea of the work accomplished. The water had all been taken out of the Poudre, together with the return water, and at a point six miles above its mouth, just below the Camp ditch, it was entirely dry. Yet, there was a discharge of 29 second-feet at its mouth carrying 80 (79.75) tons of salts, all of which must have come into the river within the intervening six miles.

§ 108. To show still further how inadequate this way of presenting the matter is, I will take the analysis of the sample from above Greeley, where the flow was 24 second-feet and the total solids 114.5 grains per imperial gallon. There were accordingly 100.8 tons of salts being carried past this point daily, but the gaging shows that there was an increase of 21 second-feet between this point and the Camp ditch, which of course increased the quantity of salts being carried by the river. The Camp ditch took all of the water in the river at this point and consequently took not only the 101 tons of salts, but much more, including the

sewage of the town of Greeley. The water returning within the next six miles came from land irrigated with this water and carried, in round numbers, 80 tons of salts. Our method shows the net results effected, but the work done by the irrigation waters is actually much greater than the figures indicate.

§ 109. The salts removed stand as follows in the order of their relative quantities; calcic sulfate, magnesic sulfate, sodic carbonate and sodic sulfate. In the case of the Arkansas river water, the sodic sulfate stands next to the calcic sulfate. The samples of ground water from the Arkansas valley which I have examined, have been very rich in total solids with much sodic sulfate. In one there was over 57 per cent of this salt and in another almost 30 per cent.

§ 110. It is true, the area in the Poudre valley under irrigation, the seepage water from which finds its way into the Poudre, is large. In 1894 it was 176,848 acres. It is now much greater, but the amount of salts carried out of the valley under the conditions of 1902 is also large. Assuming the flow of 29.1 feet of water, as found by us, to continue for 270 days—the results will be too low, for the flow is at least six second-feet below the average—we will have removed from the valley 21,532.5 tons of salts, over one-third of which is calcic sulfate, one-fourth magnesic sulfate and a little less than one-eighth sodic carbonate.

§ 111. I am not certain that the Arkansas water is comparable as a return water to these samples of Poudre water. If it is, the ratio would be materially changed and we would have 2-5 for the calcic sulfate, 1-5 for the sodic sulfate, almost 1-5 for the magnesic sulfate and very much less sodic carbonate. The analysis of this water shows a very considerable excess of bases. I have already called attention to the fact that this sometimes occurs and that I am unable to satisfactorily account for it. The alkalies and some other determinations were repeated in this analysis with excellently agreeing results. We therefore leave the excess unexplained.

§ 112. The analysis of the Platte river water gives results in agreement with those of the Poudre water and there is nothing to be gained by further discussion of this. The flow of the Platte at this point is very much larger than that of the Poudre and the amount of salts carried will be almost exactly proportional to their respective flows. All that has been said concerning the Poudre could be repeated concerning the Platte. Its water is made to repeatedly serve the purposes of irrigation. Their waters receive the sewage of several towns, the Platte proportionately more than the Poudre. The general character of the land irrigated is similar and so are the general features of the results produced.

§ 113. Too much emphasis should not be laid upon the similarities between the composition of the drain waters analyzed

and these return waters, for, as already clearly stated, the return water taken near the mouth of the Poudre must have come in within the last six miles of its course. Still it seems that the drain waters and these return waters are representative of the end results produced by water applied to our soils, and passing through it to a depth of say four and one-half feet, and then finding a free channel of escape. These similarities are clearly shown by the analyses, the average percentages of which are as follows: Calcic sulfate in return water, 44.2; in drain water, 43.9; magnesic sulsulfate in return water, 25.2; drain water, 22.4; sodic sulfate, return water, 3.3; drain water, 4.3 per cent. The reason for the omission of the Arkansas river water at Rockyford from these averages is evident from what has been previously said.

THE WATERS OF SOME OTHER STREAMS.

§ 114. The streams of this section of Colorado including the Laramie, Poudre, Big Thompson, St. Vrain, Boulder, Clear Creek, South Platte and Arkansas, have collecting grounds of essentially the same character. Some of them, it is true, receive drainage from large parks, but these are surrounded by mountains of the same character as those forming the collecting areas of the other streams. The South Platte, for instance, receives drainage from South Park, but this water, springs excepted, some of which in this case are very rich in mineral matter and others are brines which at one time were used as a source of salt, comes from the mountains. Some of the tributaries of the South Platte carry as pure water as is to be found within the state.

§ 115. The analyses of these waters will be given without comment, except such as is necessary to a reasonable understanding of the samples, some of which, like the water served to the town of Fort Collins, fail to represent the true character of the water, but represent it after the stream has become a plains stream and has already received enough seepage to perceptibly modify its composition. This applies to all the following samples with the exception of the Boulder and Clear Creek samples. The sample of Platte river water was taken from a tap in the City of Denver, but inquiry of the Denver Union Water Company elicited the fact that the water obtained was not pure Platte river water, but was a mixture of this with water from some other sources of supply. For analyses of Poudre river water see table II.

TABLE XLVII.—ANALYSIS OF BIG THOMPSON WATER, SAMPLE TAKEN THREE MILES WEST OF LOVELAND, AUGUST 20, 1902.

Analytical Results	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid	3.890	0.447	Calcic Sulfate	60.335	6.939
Sulfuric Acid	43.331	4.983	Magnesic Sulfate	11.775	1.354
Carbonic Acid	6.768	0.778	Magnesic Carbonate	11.789	1.356
Chlorin	0.565	0.065	Magnesic Chlorid	0.482	0.055
Sodic Oxid	4.771	0.549	Potassic Chlorid	0.433	0.050
Potassic Oxid	0.430	0.049	Potassic Silicate	0.257	0.029
Calcic Oxid	24.833	2.856	Sodic Carbonate	1.492	0.172
Magnesic Oxid	9.790	1.126	Sodic Silicate	7.688	0.884
Ferric and Al. Oxids	0.169	0.019	Ferric and Al. Oxids	0.169	0.019
Manganic Oxid	0.019	0.002	Manganic Oxid	0.019	0.002
Ignition	[5.561]	0.640	Ignition	[5.561]	0.640
Sum	100.127	11.514	Sum	100.000	11.500
Oxygen Eq. to Cl.	0.127	0.015	Excess	None	None
Total	100.000	11.499	Total	100.000	11.500

Total solids 11.5 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		Parts Per Million.
Total Solids	164.290	Saline Ammonia	0.030
Chlorin	2.970	Albuminoidal Ammonia	0.120
Nitrogen as Nitrates	0.300	Oxygen consumed	1.625
Nitrogen as Nitrites	None		

TABLE XLVIII.—ANALYSIS OF ST. VRAIN WATER, TAKEN THREE MILES WEST OF LONGMONT, AUGUST 19, 1902.

Analytical Results	Per Cent	Grs. Imp. Gal.	Combined.	Per Cent	Grs. Imp. Gal.
Silicic Acid	3.074	0.483	Calcic Sulfate	50.053	7.858
Sulfuric Acid	41.873	6.574	Strontic Sulfate	0.305	0.048
Carbonic Acid	7.945	1.247	Magnesic Sulfate	18.482	2.902
Chlorin	0.957	0.150	Magnesic Carbonate	7.729	1.223
Sodic Oxid	10.117	1.588	Potassic Chlorid	0.844	0.133
Potassic Oxid	0.533	0.084	Sodic Chlorid	0.915	0.144
Calcic Oxid	20.601	3.234	Sodic Carbonate	9.438	1.482
Strontic Oxid	0.172	0.027	Sodic Silicate	6.234	0.979
Magnesic Oxid	9.892	1.553	Ferric and Al. Oxids	0.199	0.031
Ferric and Al. Oxids	0.199	0.031	Manganic Oxid	0.054	0.008
Manganic Oxid	0.054	0.008	Ignition	5.179	0.813
Ignition	5.179	0.813	Sum	99.432	15.591
Sum	100.596	15.792	Excess Sodic Oxid	0.948	0.149
Oxygen Eq. to Cl.	0.215	0.034	Total	100.380	15.740
Total	100.381	15.758			

Total solids, 15.7 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		Parts Per Million.
Total Solids	224.290	Saline Ammonia	0.300
Chlorin	4.950	Albuminoidal Ammonia	0.140
Nitrogen as Nitrates	0.100	Oxygen consumed	2.026
Nitrogen as Nitrites	None		

TABLE XLIX.—ANALYSIS OF BOULDER CREEK WATER, TAKEN FROM TAP IN BOULDER, AUG. 27, 1902. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	21.985	0.6156
Sulfuric Acid	8.305	0.2325
Carbonic Acid	17.037	0.4770
Chlorin	7.425	0.2079
Sodic Oxid	6.870	0.1924
Potassic Oxid	2.720	0.0762
Lithic Oxid	Trace	Trace
Calcic Oxid	23.373	0.6544
Strontic Oxid	0.165	0.0046
Magnesic Oxid	4.760	0.1313
Ferric and Al. Oxids	1.098	0.0307
Manganous Oxid	0.340	0.0095
Zincic Oxid	Trace	Trace
Ignition	[7.607]	0.2130
Sum	101.676	2.8451
Oxygen Eq. to Cl.	1.676	0.0469
Total	100.000	2.7982

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	14.124	0.3955
Calcic Carbonate	31.317	0.8769
Strontic Carbonate	0.235	0.0066
Magnesic Carbonate	6.143	0.1720
Magnesic Chlorid	4.305	0.1205
Potassic Chlorid	4.304	0.1205
Sodic Chlorid	3.586	0.1004
Sodic Silicate	9.818	0.2749
Lithic Oxid	Trace	Trace
Ferric and Al. Oxids	1.098	0.0307
Manganous Oxid	0.341	0.0095
Zincic Oxid	Trace	Trace
Ignition	[7.607]	0.2130
Sum	82.878	2.3205
Excess Silicic Acid	17.144	0.4789
Total	100.022	2.7994

Total solids, 2.8 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	40.000
Chlorin	2.970
Nitrogen as Nitrates	0.100
Nitrogen as Nitrites	None

	Parts Per Million.
Saline Ammonia	Trace
Albuminoidal Ammonia	0.050
Oxygen consumed	1.170

* Attention is called to the similarity of this analysis to those of the Poudre water, pages 13, 14 and 15.

TABLE L.—ANALYSIS OF WATER DRAWN FROM TAP IN OFFICE OF DENVER FIRE CLAY CO., DENVER, AUG. 26, 1902.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silcic Acid	2.573	0.427
Sulfuric Acid	25.785	4.280
Carbonic Acid	14.110	2.342
Chlorin	7.508	1.240
Sodic Oxid	13.447	2.232
Potassic Oxid	1.261	0.209
Calcic Oxid	23.640	3.924
Magnesic Oxid	6.022	1.000
Ferric and Al. Oxids	0.071	0.012
Manganic Oxid	0.178	0.030
Ignition	7.097	1.178
Sum	101.692	16.874
Oxygen Eq. to Cl.	1.692	0.281
Total	100.000	16.593

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	43.853	7.280
Calcic Carbonate	9.943	1.651
Magnesic Carbonate	12.587	2.089
Potassic Carbonate	1.849	0.307
Sodic Chlorid	12.390	2.057
Sodic Carbonate	6.236	1.035
Sodic Silicate	5.218	0.866
Ferric and Al. Oxids	0.071	0.012
Manganic Oxid	0.178	0.030
Ignition	7.097	1.178
Sum	99.422	16.505
Excess Sodic Oxid	0.576	0.095
Total	99.998	16.600

Total solids 16.6 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.
Total Solids	237.142
Chlorin	21.780
Nitrogen as Nitrates	0.500
Nitrogen as Nitrites	0.540

	Parts Per Million.
Saline Ammonia	0.100
Albuminoidal Ammonia	0.180
Oxygen consumed	1.453

TABLE LI.—ANALYSIS OF CLEAR CREEK WATER, TAKEN FROM WELCH DITCH ONE MILE W. OF GOLDEN, AUG. 27, 1902.

Analytical Results.	*Per Cent*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	17.953	1.3644	Calcic Sulfate	42.252	3.2111
Sulfuric Acid	24.844	1.8881	Calcic Carbonate	6.483	0.4927
Carbonic Acid	6.870	0.5221	Magnesic Carbonate	7.707	0.5856
Chlorin	2.479	0.1884	Magnesic Chlorid	0.764	0.0581
Sodic Oxid	7.073	0.5375	Potassic Chlorid	4.017	0.3053
Potassic Oxid	3.506	0.2665	Potassic Silicate	1.578	0.1197
Lithic Oxid	Trace	Trace	Sodic Silicate	13.952	1.0604
Calcic Oxid	21.041	1.5991	Lithic Oxid	Trace	Trace
Strontic Oxid	Trace	Trace	Aluminic Oxid	2.477	0.1883
Magnesic Oxid	4.011	0.3048	Ferric Oxid	1.916	0.1450
Zincic Oxid	0.207	0.0127	Zincic Oxid	0.207	0.0157
Aluminic Oxid	2.477	0.1883	Cupric Oxid	Trace	Trace
Ferric Oxid	1.916	0.1456	Plumbic Oxid	None	None
Manganic Oxid	0.691	0.0525	Manganic Oxid	0.691	0.0525
Cupric Oxid	Trace	Trace	Ignition	7.491	0.5693
Plumbic Oxid	None	None	Sum	89.535	6.8036
Ignition	7.491	0.5693	Excess Silicic Acid	10.464	0.7953
Sum	100.559	7.6423	Total	99.999	7.5989
Oxygen Eq. to Cl.	0.559	0.0425			
Total	100.000	7.5998			

Total solids, 7.6 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		*Parts Per Million.*
Total Solids	108.571	Saline Ammonia	0.040
Chlorin	2.970	Albuminoidal Ammonia	0.140
Nitrogen as Nitrates	0.200	Oxygen consumed	2.360
Nitrogen as Nitrites	0.013		

TABLE LII.—ANALYSIS OF ARKANSAS RIVER WATER, TAKEN AT CANON CITY, FEBRUARY 2, 1898. *

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	7.840	0.847	Calcic Sulfate	18.863	2.037
Sulfuric Acid	11.676	1.261	Calcic Carbonate	34.565	3.733
Carbonic Acid	26.383	2.849	Magnesic Carbonate	17.185	1.856
Chlorin	3.699	0.399	Potassic Sulfate	1.275	0.138
Sodic Oxid	12.364	1.335	Sodic Chlorid	6.102	0.659
Potassic Oxid	0.689	0.074	Sodic Carbonate	5.305	0.573
Calcic Oxid	27.149	2.932	Sodic Silicate	11.860	1.280
Magnesic Oxid	8.193	0.885	Ferric and Al. Oxids	0.215	0.023
Ferric and Al. Oxids	0.215	0.023	Manganic Oxid	0.098	0.011
Manganic Oxid	0.098	0.011	Ignition	2.528	0.273
Ignition	2.528	0.273	Sum	97.996	10.283
Sum	100.000	10.889	Excess Silicic Acid	2.003	0.216
Oxygen Eq. to Cl.	0.834	0.090	Total	99·999	10.799
Total	100.000	10.799			

Total solids, 10.8 grains per imperial gallon.
No sanitary analysis made of this sample.

TABLE LIII.—ANALYSIS OF ARKANSAS RIVER WATER, TAKEN AT BRIDGE NEAR ROCKYFORD, APRIL 24, 1903.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.428	0.669	Calcic Sulfate	41.523	64.942
Sulfuric Acid	48.299	75.540	Magnesic Sulfate	17.899	27.994
Carbonic Acid	1.858	2.905	Potassic Sulfate	0.602	0.942
Chlorin	4.667	7.299	Sodic Sulfate	20.747	32.449
Sodic Oxid	18.662	29.187	Sodic Chlorid	7.701	12.044
Potassic Oxid	0.326	0.510	Sodic Carbonate	4.480	7.007
Calcic Oxid	17.090	26.729	Sodic Silicate	0.868	1.358
Magnesic Oxid	5.993	9.373	Ignition	4.346	6.797
Ignition	4.346	6.797	Sum	98.166	153.533
Sum	101.669	159.010	Excess Sodic Oxid	2.450	3.832
Oxygen Eq. to Cl.	1.051	1.644	Total	100.616	157.365
Total	100.618	157.366			

Total solids 156.4 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		*Parts Per Million.*
Total Solids	2,234.290	Saline Ammonia	0.065
Chlorin	103.971	Albuminoidal Ammonia	0.140
Nitrogen as Nitrates	1.500	Oxygen consumed	2.000
Nitrogen as Nitrites	0.040		

TABLE LIV.—ANALYSIS OF WATER FROM QUEEN RESERVOIR, SAMPLE TAKEN JANUARY 23, 1903.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.273	0.197	Calcic Sulfate	36.765	26.581
Sulfuric Acid	48.973	35.407	Magnesic Sulfate	23.705	17.139
Carbonic Acid	3.370	2.437	Potassic Sulfate	0.911	0.659
Chlorin	3.810	2.755	Sodic Sulfate	19.900	14.388
Sodic Oxid	17.066	12.339	Sodic Chlorid	6.287	4.546
Potassic Oxid	0.493	0.356	Sodic Carbonate	8.125	5.874
Calcic Oxid	15.095	10.914	Sodic Silicate	0.554	0.401
Magnesic Oxid	7.937	5.738	Ferric and Al. Oxids	0.075	0.054
Ferric and Al. Oxids	0.075	0.054	Manganic Oxid	0.075	0.054
Manganic Oxid	0.075	0.054	Ignition	[3.692]	2.669
Ignition	[3.692]	2.669	Sum	100.089	72.365
Sum	100.859	72.920	Excess	None	None
Oxygen Eq. to Cl.	0.859	0.621	Total	100.089	72.365
Total	100.000	72·299			

Total solids 72.3 grains per imperial gallon.

SANITARY ANALYSIS.

	Parts Per Million.		*Parts Per Million.*
Total Solids	1,032.850	Saline Ammonia	0.060
Chlorin	47.529	Albuminoidal Ammonia	0.620
Nitrogen as Nitrates	Trace	Oxygen consumed	6.415
Nitrogen as Nitrites	0.010		

§ 116. In glancing at these analyses, a few things will be noticed. First, that the waters of our mountain streams are of excellent quality and carry a small amount of salts in solution; second, that the amount of salts held in solution is materially increased almost immediately upon their entering the plains, particularly after they emerge from the foothills; third, that the waters of the mountain streams contain calcic sulfate—almost as their only sulfate—after this, carbonates and silicates; fourth, that the carbonates and silicates are rapidly exchanged for magnesic and sodic sulfates upon entering the plains (compare tables LII. and LIII.) While these samples are not strictly comparable as samples of Arkansas river water, because of the length of time elapsing between the dates on which the samples were taken, they illustrate well the differences between the mountain and plains waters. A still better illustration will be found by comparing table III, an analysis of Poudre water, with table XI, an analysis of Windsor lake water, or with table XLIV, an analysis of Poudre river water, taken above Greeley. The influence of the plains is already discernible in the composition of the water drawn from the tap in the chemical laboratory, also in samples of the Big Thompson and St. Vrain, taken a few miles west of the towns of Loveland and Longmont respectively.

§ 117. The sample of the Arkansas river water, taken near Rockyford, probably represents seepage water, but the extremely large amounts of nitrates and nitrites met with in the sanitary analysis suggest sewage. I am satisfied, however, that such is not the case, no sewage entering nearer than Pueblo, which is 70 miles above, and this is taken out by the ditches. The person who took this sample reported the water as very clear and the ditches above as taking all of the river water. We have in this sample, I believe, as good a one of return waters for the river at this point as could possibly have been obtained. It differs somewhat from the Poudre return waters in containing a good percentage of sodic sulfate. This salt is present, however, in the ground waters of this district in large quantities.

§ 118. The analysis of the water of the Queen Reservoir represents flood water which had been stored 22 months and was obtained through the kindness of Mr. W. M. Wiley. The salts held in solution differ in amount and slightly in their relative quantities, but it otherwise agrees with the seepage water taken at the bridge near Rockyford. This may be due to the return waters entering the river during flood time, but this would seem to indicate a very great in-flow of return waters at such a period, and it would seem that a portion, at least, of these salts must find their way into the water, either in the ditch or reservoir, during the period of storage. The Arkansas river in the month of February,

a month of low water, carried only 10.8 grains. This flood water, after storage for twenty-two months, carried 72 grains. Our data is not sufficiently full to enable us to go further with this discussion.

§ 119. The work done by the irrigating waters of the Arkansas valley is evidently similar to that done by them in the Poudre valley, and so far as the rate at which the salts are carried out of the soil is indicated by the contents of total solids per gallon, it is very nearly the same, differing principally in carrying a fairly large percentage of sodic sulfate, while the Poudre return water carries relatively but little or none of this salt.

THE SUSPENDED MATTER CARRIED IN TIMES OF HIGH WATER.

§ 120. This will vary both in amount and character, according to the conditions prevailing within the drainage area of the streams carrying it. The Rio Grande, in New Mexico, would scarcely be expected to carry the same character of suspended matter, especially after a torrential rain somewhere within its plains section, as at Del Norte, Colorado, after a similar rain in the mountain districts to the west of it.

§ 121. The amount of sediment, as I have found it, has been a great disappointment to me, it being very small in amount compared with my preconceived notions, and of a somewhat different quality.

§ 122. On May 22, 1902, we had an excellent opportunity of obtaining a sample of Poudre flood water, caused by a heavy rainfall within the foothills, whereby the river was swollen to such an extent that it passed beyond its bounds. It carried on this date 12,000 second-feet, or about ten times its usual volume at this season of the year. This water was very thick with mud and debris, such as the unusual volume of water would tear loose along its course. I had a large sample, 102 pounds, of this water collected from the middle of the stream. The bucket with which the water was dipped was allowed to sink as far as it would in such a current. The whole sample was allowed to settle for several days, on account of the suspended clay, and then filtered. The suspended matter amounted to 0.213 per cent, or 2,130 parts per million. The analysis of the sediment gave the following results:

TABLE LV.—ANALYSIS OF SUSPENDED MATTER CARRIED IN FLOOD WATER OF POUDRE RIVER, MAY 22, 1902.

	PER CENT.
Silicic Acid	61.482
Sulfuric Acid	None
Carbonic Acid	0.350
Chlorin	Trace
Phosphoric Acid	None
Potassic Oxid	2.663
Sodic Oxid	1.519
Calcic Oxid	2.575
Mangesic Oxid	1.948
Ferric Oxid	6.826
Aluminic Oxid	7.866
Manganic Oxid	0.461
Moisture	8.040
Ignition	6.485
Total	100.213

Nitrogen 0.306 per cent.

§ 123. Our people do not have opportunity to apply such water in irrigating, and there is but little object in calculating what the value of an acre foot of it would be, still some may be curious to see the figures. The total suspended matter per acre foot would be 5,799 pounds. The total potash (K_2O) would be 154 pounds; the total nitrogen, 17 pounds, and the total organic matter 377 pounds.

§ 124. While the suspended matter, in this case, came from the foothills, it is not so different in its composition from that usually carried by this stream as would be anticipated.

§ 125. A sample of Arthur ditch water was taken July 5, 1900, when the river was high, and the water much more turbid than usual. The percentage of suspended matter was found to be only 0.0016, 16 pounds per million, or 44 pounds per acre foot. The sample taken was sufficiently large, over 100 pounds, to give entirely trustworthy results. The analysis was made by fluxing with calcic carbonate, therefore the lime and magnesia are included in the undetermined. The analysis gave the following results:

TABLE LVI.—ANALYSIS OF SUSPENDED MATTER IN ARTHUR DITCH WATER, SAMPLE TAKEN JULY 5, 1900.

	PER CENT.
Silicic Acid	58.858
Potassic Oxid	2.818
Sodic Oxid	1.998
Ferric Oxid	6.985
Aluminic Oxid	11.505
Ignition	9.722
Undetermined	8.084
Total	100.000

§ 126. The potassic and sodic oxids in these two sediments are nearly the same; the silicic acid, iron and aluminic oxids are as nearly so as we could expect to find in samples taken on different days, with like conditions prevailing in the river, instead of samples taken under very unlike conditions. In this case, these samples show that there is very little difference in the suspended matter brought from the mountains by the flood water, produced by the melting snow, and that carried into the river by torrential rains within the foothills. This remark applies to the inorganic constituents only, and would not be strictly applicable to heavy rains falling within the sections where the red clays of the jura-triassic abound. The ignited suspended matter of May 22, shows an abundance of red clay.

§ 127. The Queen Reservoir was filled with flood water from the Arkansas river. As the reservoirs, of which this is only one, are filled in this manner for the most part, I obtained through the kindness of Mr. W. M. Wiley a sample of the silt deposited in this reservoir. This matter had evidently been some time in accumulating. It is difficult to see how this may have been silt carried by the flood waters of the Arkansas, and yet the judgment of Mr. Wiley and his assistants ought to be thoroughly reliable in this matter. When passed through a fifty mesh sieve 15 per cent of it remained upon the sieve. Before ignition, bits of coal were easily recognizable among the large fragments of roots, stems, etc. It is possible that these bits of coal had been swept along by the flood waters from Canon City or Pueblo. After ignition the mineral and rock particles recognizable were mica, quartz, felspar and grains of a vesicular igneous rock, probably andesite. The latter was abundant. There were also fragments of shells and pear-shaped bodies, being quite sharp at one end. Some of these were spirally marked, others apparently not. These bodies dissolved in hydrochloric acid with effervescence, and were probably seed or spore cases of chara.

§ 128. I am not familiar enough with the country to suggest any source for the particles of igneous rock, but if I have made no mistake they have probably been transported a long way. The part that passed through the sieve was separated into a coarser and finer portion by washing. The particles of the coarser part of this portion were largely quartz, some felspar and mica grains and also some of the eruptive rock. Such was the mechanical composition of this silt. The chemical analysis gave the following results:

TABLE LVII.—ANALYSIS OF SILT FROM QUEEN RESERVOIR, PROWERS COUNTY, COLO., SAMPLE TAKEN JAN. 23, 1903.

	PER CENT.
Silicic Acid	69.262
Sulfuric Acid	0.080
Carbonic Acid	2.819
Phosphoric Acid	0.120
Chlorin	Trace
Sodic Oxid	1.401
Potassic Oxid	1.807
Calcic Oxid	4.904
Magnesic Oxid	1.081
Ferric Oxid	3.603
Aluminic Oxid	10.428
Manganic Oxid	0.082
Ignition	4.283
Total	99.870

Nitrogen, 0.075 per cent.

§ 129. The elements of plant food contained in this are the potassic oxid, the phosphoric acid, and perhaps the lime and the organic matter. The exceedingly low content of nitrogen indicates that the value of the organic matter is small. This silt differs from the two previously given in carrying a little phosphoric acid. This may come from the rock particles or from the shells, and may be from fragments of bone, a few of which were found in the silt. The chief value is in the potash, forty pounds per ton, but I can see but little difference between this potash, which, for the greater part at least, is contained in the felspar in the silt, and potash contained in any other finely divided felspar. The only question involved is the one of the degree of fineness. The quantity of potash is small, scarcely greater than that contained in an acre foot of some irrigation waters, especially those which have been stored—an acre foot of the Queen Reservoir water carrying 72.3 grains per gallon, and the salts in solution containing 0.5 per cent of their weight of potassic oxid, contains fourteen pounds of potassic oxid, while a ton of the silt carries forty pounds, every whit of which has to be brought into solution. The three samples of suspended matter, or silts, which have been presented represent very different conditions, and yet the composition is essentially the same. We find the mineralogical constituents the same, and essentially the same percentages of potassic oxid in the two from the Poudre, but less in the third, representing the lower Arkansas, and in none of them is it high, 2.9 per cent in round numbers.

§ 130. The fourth sample of suspended matter, of which I shall give an analysis, is of an entirely different nature. This material is not soil, or the natural products of decay on the surface of the crust, but refuse from mills, the products of decay formed in veins, comminuted gangue rock, slimed ore, etc., which is discharged into the water course and carried by the

stream, even to the distributing furrows in the fields. The analysis of this material gave the following results:

TABLE LVIII. — ANALYSIS OF SUSPENDED MATTER IN WELCH DITCH, SAMPLE TAKEN ONE MILE ABOVE GOLDEN, AUGUST 27, 1902.

	PER CENT.
Silicic Acid	53.991
Sulfuric Acid, Sol. in HCl	0.084
Sulfur	1.908
Ferric Oxid	9.420
Aluminic Oxid	15 822
Manganic Oxid	0 636
Calcic Oxid	1.015
Magnesic Oxid	1.613
Zinc	0.383
Copper	0 201
Lead	1 214
Potassic Oxid	4 650
Sodic Oxid	1.057
Loss at 60°	2.386
Loss above 260°	5.495
Total	99.875

Nitrogen 0.121 per cent.

§ 131. The suspended matter amounted to 0.149 per cent. of the weight of the water, equal to 4,056 pounds per acre foot, carrying 4.9 pounds of nitrogen and 190.6 pounds of potassic oxid. This mud is richer in these elements of plant food than the mud of flood waters. The lead, copper and zinc found indicate the presence of 1.402 per cent. of galena, 2.502 per cent. of pyrites, 0.517 per cent. of sphalerite or zinc blende and 0.581 per cent. of chalcopyrite. These quantities of these minerals have escaped the concentrators and failed to be deposited before they reached this point. We have here to deal with a mixture of clay and felspar, a conclusion entirely in harmony with the facts known concerning the concentrating ores in this district.

§ 132. It appears from the results of the examination of these sediments, that they are composed essentially of the finer particles formed by the decay and comminution of the rocks forming the mountains, or rock particles forming the soil, which in our case amounts to saying the same thing. Our soils contain, as their mass analysis shows, a little over two per cent of potassic oxid, 2.2 to 2.6. These sediments contain less than the soils, except in the case of the mud from Clear Creek, which contains about as much as ordinary granite, 4.6 per cent. These results confirm an opinion which I have long entertained, i. e., that there is danger of our overestimating the value of the silts carried by our streams, as it seems almost impossible for this silt to be other than it appears to be from the study of the silts themselves, and the analysis thereof; namely, a mixture of the fine particles of the minerals constituting the mountain masses of the country.

SUMMARY.

1. The general character of the water of our mountain streams is dependent upon the character of their collecting area and is essentially the same for the streams studied in this bulletin.

2 The character of the water changes rapidly as soon as it leaves the mountain section of its course and enters the plains.

3. In the case of the Poudre water, used by the town of Fort Collins, the total solids contained in the water increases from 2.9 grains per imperial gallon, in the mountain section, to an average of perhaps 10.2 grains as delivered to the town, an increase of three and one-third times the original amount present.

4. This change is produced by its flowing through less than eight miles of its course lying within its plains section.

5 The mineral substances held in solution by the water, as mountain streams, are derived principally from the felspars by the action of water and carbonic acid. Pure water attacks these minerals, but its action is greatly increased by the presence of carbonic acid.

6. Our river and ground waters contain both strontia and lithia, which are shown to be dissolved out of the felspars by carbonated waters, and which are therefore to be considered as their source.

7. The amount of mineral matter which the Poudre carries through its canyon daily, assuming a flow of 300 second feet, is nearly twenty-six tons, equal to 520 cubic feet of solid rock, having the average density of quartz.

8. The Poudre water is not nearly saturated, for by direct experiment with finely ground felspar we were able to bring 4.536 grains into solution in each imperial gallon.

9 The composition of the material dissolved out of the felspar by water and carbonic acid, is almost identical with that held in solution by the river water.

10. The organic matter in the river water is not large in quantity and, while probably of vegetable origin, became exceedingly offensive when the water was evaporated to a small volume

11. The waters of the Boulder and Clear Creek agree closely in composition and character with that of the Poudre.

12. The influence of the plains section of the stream upon the character of the water is increased by the irrigation of the adjacent lands.

13. The effect of storage is to increase the mineral matter held in solution. Some of the increase is derived from the ditches through which the water flows and from seepage directly into the reservoirs.

14. A small increase, 0.5 grains per gallon, is due to evaporation, but by far the largest increase is shown in instances where seepage water is either intentionally stored or flows into the reservoir.

15. In the case of Terry Lake the total solids found in two different years were 134.5 grains and 175.6 grains per imperial gallon. The average of which shows that this lake held in solution 27,127 tons of solids in its 9,000 acre-feet of water.

16 Windsor Lake, containing 14,000 acre-feet, held 18,894 tons in solution.

17. The water with which these reservoirs were filled was taken, for the greater part, directly from the Poudre, and the rest of it indirectly, it having in the meantime passed into the soil and reappeared as seepage.

18. The mineral matters held in solution in the different reservoirs differ considerably. Those of Terry Lake resemble in their composition

the alkali incrustations, which appear in many localities; those of Long Pond and the Windsor Reservoir resemble the water soluble portion of the soil, rather than the efflorescent alkalies. The water of Warren's Lake has suffered less change in the character of the salts held in solution than the others, and yet, the sulfates compose rather more than 50 per cent. of the salts held in solution.

19. The salts predominating in the water of the Poudre, while it is a mountain stream, are the carbonates, with some chlorids and sulfates, but as, stored in Terry Lake and Windsor Reservoir, the carbonates have almost disappeared and their place has been taken by the sulfates.

20. The amounts of calcic magnesic and sodic sulfates which appear in the stored waters are large. We find in Terry Lake 5,859 tons of calcic sulfate, 10,616 tons of magnesic sulfate and 7,113 tons of sodic sulfate. In the Windsor Reservoir we have the same salts, but in different quantities, 6,083 tons calcic sulfate, 7,029 tons of magnesic sulfate, 1,999 tons of sodic sulfate. These are the salts which constitute our alkalies.

21. The only constituent contained in these stored waters which, under our conditions, may have any great interest or significance as a plant food, and consequently tend to maintain the fertility of the soil, is the potash, K_2O. The quantity of potash held by the stored waters is not great. The aggregate amount present in the four lakes discussed is 188 tons, contained in 27,672 acre-feet of water, which, allowing two acre feet of water to an acre of land, would give an application of fifty pounds of sulfate of potash to the acre, which undoubtedly tends to maintain the fertility of the land to which it is applied

22. The potash contained in the stored waters is largely brought into the reservoirs by seepage or other than river water.

23. The application of two acre-feet of river water as it flows through the canyon would give only 12.5 pounds of sulfate of potash per acre, or exactly one-fourth as much as the stored waters. As the seepage water contains not more than one-third of the latter in either of these cases, it follows that the amount of potash carried by it and neccessarily obtained from the soil through which it has seeped, is much greater than that carried by pure river water, and we may note that the quantity indicated is greater than that carried by drain water or by soil water, as a rule, but is less than that carried by off-flow water, and sometimes by soil water.

24. The amount of nitrogen, including all forms, added with the irrigation water, being less than four pounds per acre, is negligible.

25. The quantities of useless, or even deleterious salts, added to the soil by the application of two acre-feet of stored water to an acre of land, are worthy of consideration. In the case of the Windsor Reservoir we add the equivalent of 54 pounds sulfate of potash, and at the same time 5,347 pounds of other salts; in the case of Terry Lake we add 55 pounds of sulfate of potash and 11,349 pounds of other salts.

26. Water used in direct irrigation, that is, water conveyed by means of ditches directly from the river to the land irrigated, suffers less change than when stored, but does not by any means escape altogether. The best measure that I have of the extent of this change, and one which, judging by the extent that the water supplied to Fort Collins is changed in flowing less than eight miles, is not an extreme or an exaggerated one, indicates that the total solids are not less than five times as much as in the river water when the ditch was not more than ten miles long.

27. The water used in irrigating, in order to study its changes, was water taken directly from the river, so far as we could obtain such. The general results may be stated as follows:

28. The water flowing over the soil carries, in the first portions which flow off, very considerable amounts of salts in solution. The samples which gave the most reasonable results indicated that water flowing for 600 feet over the plot experimented with, carried between 800 and 1,000 pounds more salts in solution, per acre foot, than the on-flowing

water. The first water that flowed off gave much higher results, but subsequent samples showed a rapid falling off.

29. The water entering the soil caused the solution of not less than 4,400 pounds of salts per acre-foot, and probably very nearly three times this amount.

30. The salts taken into solution by the water entering the soil and becoming ground water, are calcic, magnesic and sodic sulfates. The salts dissolved in the next largest quantities were sodic chlorid and sodic carbonate.

31. The amount of salts brought into solution in the ground water, due to the application of water to the surface, varies not only in the total amount of salts, but also in the relative quantities of the individual salts. The salt that went into solution the most freely in 1898, that is, the salt that showed the largest increase in the ground water, due to the irrigation of the plot with which we were experimenting, was sodic sulfate, for which we found an increase of 1,430 pounds in each acre-foot of ground water. In 1899, the largest increase was shown by calcic sulfate, an increase of 1,638 pounds per acre foot.

32. In 1898 there were two causes which may have contributed to bringing about the relatively large increase of the sodic sulfate. One was the scanty supply of water, which did not enable us to fill the soil with water to the same extent that we did in 1899, so that the relative mass of water to that of the soil, or to the salts in the soil, was not the same. This is an important condition and one, for the effect of which we have no measure. The other was the necessity that we were under of excluding the water of well D. from our consideration of the results of this irrigation, because of an accident. The results shown by this well subsequently indicate that it would have showed a greater increase in the amount of calcic sulfate than the other three, and would consequently have reduced the relative increase of sodic sulfate. The general results were slightly influenced by this omission. Still, after all due allowance for these facts has been made, there remains a decided difference in the results of these two experiments, one in 1898, the other in 1899.

33. The character and supply of the water exert an influence upon the relative quantities of the salts that go into solution, but there are evidently other factors that influence these ratios. The general conditions of the soil, the temperature and the season of the year, including all the meteorological conditions, probably have a great influence upon the salts in the soil, and the relative quantities of them in solution in the ground water.

34. The effect of a long continued rain in the spring of 1900, when the temperature of the water entering the soil was not far from zero, as the ground was covered with melting snow, is given in Tables XXXVI, XXXVII and XXXVIII. The salt present at this time, April 9, 1900, in well A, in the largest quantity, was magnesic sulfate. The quantity of this salt present, on this date, was between four and five times greater than the average quantity present during the season of 1898. The quantities of calcic and sodic sulfates were also greater than their respective average quantities for the same time; that of calcic sulfate was one-third higher, while that of sodic sulfate was between five and six times greater. The increase of the sodic sulfate over its average quantity for 1898, is greater than that of the magnesic sulfate, but the amount of the former salt present is just a little more than one-half that of the latter.

35. The following general conditions may have contributed in bringing about these variations. The weather during the preceding weeks, or even months, also the abundant supply of water simultaneously over a large area. I conceive this last condition to differ very greatly from the application of even a copious irrigation applied to a limited area of soil.

36 It is a common observation that the alkali salts effloresce freely during the winter season. It may have been the case in this instance that an unusual amount of this salt, magnesic sulfate, had accumulated in the upper portions of the soil, owing to evaporation during the preceding winter. Such a result is suggested by the presence of this salt in

large, sometimes predominating quantities, in the effloresced alkalies, but I have no other observed fact to support it.

37. The very large quantity of magnesic sulfate present may also be accounted for by supposing that the ground water, under the then obtaining conditions, actually dissolved larger quantities of this salt out of the soil than of the others.

38. It is not clear from any facts which I was able to discover, to which of these conditions, if to any of them, the observed fact ought to be attributed; to the accumulation of the magnesic salt in the upper portion of the soil, due to evaporation from the surface and the consequent action of capillarity, to low temperature, to the abundant supply of water over a large area, or to some other unrecognized cause.

39 The fact is simply this, that the salts in the ground water are essentially the same at all times, and the application of water to the surface, whether it be irrigation water or rainfall, does not change in any material way the salts present. The relative quantities in which they are held in solution in the ground water varies quite widely, while the causes of the variations are not evident. It is not probable, for instance, that the quantity of magnesic sulfate in the soil experimented with, predominates at any time over the calcic sulfate, as the relative quantities of these salts found in the ground water in the spring of 1900 might be held to suggest. The solution obtained by thoroughly exhausting this soil with water, shows that there is from two to three times as much calcic as magnesic sulfate in the top four inches of it. The total lime contained in this soil, as shown by analysis of the whole soil, is in round uumbers, double that of the magnesia. The lime in the hydrochloric extract of this soil usually exceeds the magnesia; in the subsoil it is even eight times as great.

40. The ground waters, under ordinary conditions, always contain more calcic than magnesic sulfate, but under the conditions prevailng during the spring of 1900, we find the rule reversed—see analyses XXXVI, XXXVII and XXXVIII. The cause, or causes, of this were evidently not permanent, for within a period of eight days we observe a change, in which the ratio of magnesic to calcic sulfate, in the water of well A, falls from 2:1 to 1.2:1, a ratio which had already been found for these salts immediately after irrigation. In the drain water taken on the same date, April 20, 1900, we observe the usual ratio between these salts. The drain water is at all times different from the ground water, and too much stress should not be placed upon the ratio of these salts observed in it. Its chief value, in this case, is to show that, though the conditions in regard to temperature, water supply, etc., were general, they have produced no noticeable effect upon the kind or relative quantities of the salts carried in the drain water.

41. The water of well A, on April 9, 1900, was intermediate in the character of the salts held in solution between the alkali-incrustations forming on this soil, under favorable conditions, and the water usually present in the well. It differed from the former in having less sodic sulfate, and from the latter in carrying less calcic sulfate and very much more magnesic and sodic sulfates. These facts do not seem to be in any way dependent upon the solubilities of the salts themselves, nor upon any known state of hydration.

42. The quantities of potash involved were not large, being 15.1 and 19.2 pounds respectively, for the two seasons, 1898 and 1899. These quantities are extremely small, when we consider the mass of other salts which was brought into solution. In 1898 we have nearly 2.25 tons, in 1899, 2.5 tons of salts brought into solution, and this on plainly too conservative an sstimate, while only these small quantities of potash are carried along with them. If we were to treat an equal amount of ground granite with this amount of water, it would dissolve out more potash than is here shown to have gone into solution, notwithstanding the tendency of such a large quantity of salts, 2.5 tons, to carry others into olution. This is entirely in accord with facts observed long

ago, i. e., that the soil retains potash salts more tenaciously than it does others.

43. The drain waters, as indicated by such data as we have been able to gather, though we have not been able to study this subject as we desired, differ materially from the ground waters. They contain a smaller quantity of salts in solution, and are more uniform in this content than the ground waters. The salts present stand in a different order, especially in regard to their relative quantities, sodic sulfate sometimes disappearing entirely. Calcic sulfate is uniformly first in quantity; magnesic second, sodic carbonate third, and sodic chlorid fourth, with sodic sulfate quite irregular, but usually less than the sodic chlorid.

44. The first significance of these facts is that our drains benefit our lands by removing the surplus water, rather than the useless or deleterious salts, from the soils. This is by no means a small service. Indeed, it is the most important service to be rendered to nearly all of our alkalized land. Of the salts removed, the most injurious one, when present in sufficient quantity, is the sodic carbonate. Relative to the amount of this salt present in the drain and ground waters, a comparison of the analyses of the drain waters with those given of ground waters in this Bulletin, and also with those in Bulletin No. 72, pages 23-26, it will be seen that the grains per gallon remain quite constant. In other words, the sodic carbonate does not seem to be retained by the soil, or removed from solution by passing through it, while the sodic sulfate, or white alkali, is retained to a very marked extent.

45. The only samples of drain and ground waters taken on the same date, are those taken April 17, 1900. The samples of ground water are unusual, as set forth in preceding paragraphs, but the features to which I wish to call attention are so bold that they will not be hidden, or even distorted by these facts. In the ground waters we have 452 and 470 grains respectively, in the drain water 114 grains of total solids. The sodic carbonate in the ground waters amounts to 26 and 22 grains respectively in the drain water 23 grains. The range of this salt in the ground waters, given in this Bulletin, is from 10 to 28 grains per imperial gallon, and in those given in Bulletin No. 72, it is from 9 to 18 grains, while the range of the same salt in the drain waters given in this Bulletin is from 11 to 23 grains. Returning to the samples of April 17, we have in the ground waters 76 and 115 grains of calcic sulfate per gallon, for the drain water 45 grains. We have 152 and 137 grains magnesic sulfate per gallon for the ground water and 24 grains in the drain water. Still more marked than either of these is the case of the sodic sulfate, of which we have 105 and 89 grains respectively in the ground waters, and 5 grains in the drain water. The sodic chlorid is also retained within the soil, but in a less degree than some of the other salts. The ground waters on this date, April 17, 1900, carried 56 and 64 grains respectively, while the drain water carried 7 grains per gallon, or one-eighth as much as one of the samples and one-ninth as much as the other.

46. The analyses of the ground water before and after irrigation show that one of the effects of irrigation is to rather increase the relative amount of sodic chlorid in the ground water, so that the above figures appear more favorable to my statement than the facts as they are found, under less extreme conditions, might appear. Reference to the analyses of ground water, given on pages 30-33 and 38-40 of this Bulletin, and to those given on pages 21-26, Bulletin No. 72, will show that the sodic chlorid in the drain waters is less than in the ground waters, under the wide range of conditions represented by these numerous samples. Some of the analyses referred to, especially some of those in Bulletin No. 72, suggest very pointedly that the character of the soil has a decided influence upon these points; the indications being that the soil experimented with permitted the respective salts to pass through more freely than soils freer from alkali salts, and in better mechanical condition, would have done.

47. The amount of potash salts removed by the drain water is less than that existing in solution in the ground water. The total amount removed in the course of years is a large one and, while we are reminded that the draining is going on all the time, day and night, year after year, we have to consider also that potash is not taken from any single acre-foot of soil, nor from a mass represented by a single acre of surface, but for the sake of keeping our numbers within limits which we can appreciate, I will give the figures showing the amounts of potash, on the basis of the acre-foot. One acre-foot of our soil contains a total of 78,750 pounds. Of this dilute hydrochloric acid dissolves 43,750 pounds. An acre-foot of ground water, before irrigation, in 1898, contained 22 pounds, and in 1899, 6 pounds of potash. After irrigation, in 1898, it contained 41 pounds, in 1899, 18 pounds. An acre-foot of drain water carries but 5 pounds, taking the average of four drains. The water draining from any given acre of land is probably small, not exceeding a hundredth of an acre-foot daily, in which case the amount removed from any single acre of land is very small. We will put this another way, in which the statements may seem more definite. If we take a strip of our land 18 miles long and one mile wide, from which there is discharged 30 acre-feet of drainage water daily, it would take upwards of 50,000 years for it to carry out an amount of potash equal to that contained in the first three feet of soil.

48. The nitrogen carried by the drain waters is only a little more per acre-foot than the potash, it being 5.8 pounds. The supply of nitrogen in the soil is not so great as that of the potash, by any means, but while there is no accession of potash, except it be added, there may be of nitrogen. The amount found in the first two acre-feet of our soil was 7,000 pounds, and it would take 1,227 acre-feet of drain water to contain this much nitrogen.

49. The return waters furnish us a bigger and slightly different measure for the effects of drainage, and as this, with us, is mainly due to irrigation, they furnish us, perhaps, the best criteria by which to judge of the effects of irrigation upon our lands. We would expect to find their composition very similar to that of the drain waters, provided our samples of drain water were numerous enough to represent the various soils and conditions to be met with in the 176,848 acres of land nominally under irrigation within this valley, of which probably 140,000 are actually irrigated. This remark applies, of course, to the Poudre Valley and river.

50. We find the total solids in the return waters lower than in the ground waters, and having the same range as found for the drain waters. We find them characterized by the same salts, and in the same order in regard to their relative quantities; i. e., calcic sulfate, magnesic sulfate and sodic carbonate, with sodic sulfate irregular in its quantity, but always subordinate, except in the sample of Arkansas river water, taken at Rocky Ford, April 24, 1903, concerning which some doubts may be entertained, but which is probably correct, because the ground waters of that section are extremely rich in sodic sulfate.

51. The salts discharged by the Poudre into the Platte river do not amount to less than 22,000 tons annually, which come from the lower section of the river, besides what may be carried from sections further up the river when the waters are not all taken out, as was the case at the time our samples were taken.

52. The chief difference between the drain waters and the return waters taken from the rivers, is in the potash present, which is greater in the return waters than in the drain waters. While some of the drain waters contain almost as much potash as the return waters, the latter are, as a rule, richer in potash than the former. The main features of these two classes of waters are, however, identical.

53. The waters of other streams, which we examined fully, justify us in assuming that the Poudre river water is typical of the mountain waters on this side of the range. They show that the waters of the different streams, while in their mountain sections, are identical; that all

alike suffer changes on entering the plains, and their return waters, as represented by the Platte river below the mouth of the Poudre, indicate that the changes suffered by them are, in all essential particulars, the same.

54. These mountain waters are interesting and worthy of fuller and more detailed study than is proper to devote to them in this place. Therefore the discussion of them will be omitted, except one feature of the Clear Creek sample. Clear Creek presents an instance of a stream whose waters are laden with the mud and slimes from many mills, and whose waters are also used for irrigation. The sample analyzed was taken from an irrigation ditch. A full and careful analysis was made of it, a fuller and more careful one than would probably have been made in the case of a legal controversy, and yet it shows nothing that can be interpreted as a serious pollution of the water. The essential characteristics of a pure mountain water have scarcely been modified in the least. The purest mountain water in any of these streams carried 2.6 grains per imperial gallon, Poudre river water, sample taken July 30, 1902. The sample of water taken from Clear Creek, a stream which drains a section of country with a population of at least 25,000 souls, and receives indefinite quantities of mine water, and the refuse from twenty odd mills, carries less than eight grains to the imperial gallon, an increase which is less than that caused by a flow of a few miles (four to eight) in the plains section. Of the heavy metals, salts of which we might expect to find in this water, due to oxidation of the ores treated in the mills, we find none, a trace of zinc oxid, 0.0157 grain in each imperial gallon, excepted.

55. The suspended matter in our streams and ditches was found to be very much less than was expected, even in time of flood, due to heavy rains in the lower and, largely soil covered sections of the mountains, or in the foothills. The water, at the time the first sample given in the text was taken, corresponded to the colloquial expression, "as thick as mud." The season was one of high water, when the usual flow is 1,200 second-feet, due to the melting of the snow, but at this time it was ten times as great, or 12,000 second-feet. The rain fell in a hilly section and the fall of the river being great, we had conditions favorable to the tearing loose of soil, rocks and other debris. The crest of the flood had not passed at the time the sample was taken, and the amount of suspended matter in this sample probably represents the maximum that we may expect to find in this stream at any time. The amount of sediment equalled 3 tons per acre-foot of water. The aggregate amount of sediment carried by such a flow, 12,000 second-feet, laden as this was, is not far from 2,800 tons per hour, all of which, it is true, must sooner or later be deposited somewhere, and in considering this as a source of fertility we permit the impression of this big aggregate, and the fact that it is deposited somewhere, to lead us to form too high an estimate of its actual available amount, and we at the same time assume that it is feasible to apply it to the land. If it were feasible and we applied two acre-feet of it to an acre we would add six tons of this suspended matter to the acre. This would, if spread evenly over the surface of the acre, form a coating less than 0.04 of an inch in thickness, or twenty-five such floodings would, under very favorable conditions, furnish a dressing of this sediment one inch in thickness. This would, of course, if rich in plant food, be a very desirable addition to the acre of land. There are, on the other hand, several considerations to be weighed before we set this gain down as an easily attainable fact. It is not a fact that we can apply this muddy water to our land when it is in the river, and the occasions when it is in the river are very seldom; this one scarcely having been equalled since the occupancy of this valley by the white man, except once, when it was due to the breaking of a dam. The facts on which the assumed supply of sediment is based, are wholly exceptional. But if we grant the supply, the question of value is an open one, and here, as in the question of quantity, we permit our judgment to be imposed upon. In that case the large total, and the fact that it is deposited, leads us to the

conclusion that it is deposited in large quantities on the soil we have in mind. In this case the color and fineness of the sediment make a general impression of richness upon our minds, and we forthwith accept it as an established fact when it is not. The composition of this sediment does not justify the inference.

56. This sediment, very naturally, resembles in composition the source from which it was derived, which was the soil of the mountain or hillsides and their valleys. These soils have a common source with those of the plains, and it is therefore, on reflection, no matter for surprise that the sediments should not be found to be richer than the latter. There are two respects in which the sediments, in some measure, differ from the soils on which they would be deposited in our case, but this measure is not very great. These two respects are the fineness of division and the amount of organic matter contained in them. The fineness of the sediment is a condition favorable to the alteration of those mineral particles containing elements of plant food, whereby these latter are made available. The amount of organic matter contained is larger than in the average of our plains soil, but is not large when considered by itself. The case resolves itself to about this, that the 0.04-inch of sediment, which an application of two feet of water to an acre of our soil would add, would be equivalent to adding a layer of the same soil only a little more uniformly fine and containing a little more organic matter.

57. The sediments from the ditch waters are of the same character, and resemble more closely still, the soils to which they would be applied with the water.

58. Another sample of sediment examined was one which had been carried by flood waters and deposited as silt in a reservoir, the Queen reservoir, Prowers County, Colo. The mineralogical and chemical composition of this suggests the same considerations, and points to the same conclusions that I have endeavored to set forth in discussing the sediment carried by the flood water of the Poudre. This sediment, however, is less suggestive of the probability of any considerable benefit accruing to the land by its application to it.

59. The fourth sediment examined was of an entirely different origin, and naturally of a different character, and certainly ought to be looked at from two different and opposite points of view. The practically more important one being in regard to the possible injurious effect which any minerals present in it might have upon the vegetation to which it might be applied with the water. The other point of view is the same as that from which we have briefly considered sediments carried by our streams in general.

60. The analysis of the sediment answers the question relative to the presence of minerals, either injurious in themselves, or by the products of their decomposition, in the negative. The amounts of sulphid of lead, zinc, copper and iron do not exceed 35 pounds per ton of sediment, or if the whole of the sulfur found were present as iron pyrites, probably the most dangerous form in which it is likely to be present, the total amount would be 43 pounds per ton, about 86 pounds per acre-foot of water, a quantity, of itself small, and which can be reduced by the use of settling ponds, or other settling devices.

61. From the second point of view the quantity is not only materially in excess of the quantity carried by our streams in times of ordinary high water, but actually carries more potash, nitrogen and organic matter, the former constituting the principal value in either case.

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Bulletin 83. October, 1903.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Irrigation Waters and Their Effects.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903.

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FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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IRRIGATION WATERS AND THEIR EFFECTS.

BY W. P. HEADDEN.

I shall endeavor to set forth in general terms some of the broader features of the questions pertaining to the changes caused by irrigating our lands, without making any attempt to go into details, or any pretense to a thorough discussion of the questions connected with this subject. The following pages are intended as a brief or popular bulletin, presenting some of the conclusions arrived at in bulletin No. 82, but are entirely independent in the manner of presentation.

The waters used for irrigation in earlier years were really derived directly from the melting snows of the mountains to a much greater extent than at the present time. The cold of the higher altitude of the mountains was then the only cause preventing the waters falling in these regions, or formed by the melting of the snow, from flowing rapidly from the place of their precipitation to the lower reaches of the rivers, through which they find their way to join the oceanic waters. This agent is as active now as then but alone it is inadequate to effect a sufficiently regular distribution of these waters to meet the varied and growing requirements of agriculture, and it has been supplemented by the use of reservoirs to store the waters and prevent them from going to waste. Not only has the attempt been made to store the flood

and other surplus waters in order to subsequently distribute them, that they might add to the well-being and prosperity of those living in sections further down the stream, but our agriculture has so increased that much more water is required than formerly, and in order to meet this requirement our reservoir systems have constantly grown. All available sources of water are rapidly being made to render service, until the waters of the mountains are taken out of the streams and returned several times, before being finally discharged into the bigger streams of which their natural channels or smaller streams are confluents. We may yet learn to further increase the duty of water, but if we do we will not lessen the questions relative to the changes produced and suffered by these waters used for the purposes of irrigation. We will, on the contrary, intensify them and probably find that new questions will be raised.

It is well known, but still more generally accepted as a fact, that the waters of rivers rising in high mountains where there is little soil, a scanty vegetation and no human beings to pollute them, are comparatively pure, many of them very pure indeed. This is the case with the waters of our mountain streams and is not a fancy arising from the notions which we associate with the mountains and their seclusion. The rocky face which their surface so generally presents does not wholly withstand the attack, gentle though it seem, of the falling rain or melting snow. The rocks yield little by little it is true, but the water is never able to enrich itself greatly in mineral matter at their expense. The work done by the waters in a year, a month, or even in a week, when measured in the aggregate is surprisingly large, but no given quantity of this water, a gallon or so, carries more than an infinitesimal part of the product. This water is usually colorless and free from organic matter because we have no accumulation of decaying organic matter such as peat, etc. to contaminate it. Where the surface is covered with soil there is little difference between the soil and the rocks on which the soil rests. I do not know whether the changes which take place in this soil proceed more rapidly than in the rocks proper or not; it is presumable that they do, but they are essentially of the same kind and this is true throughout the mountain region. These waters suffer little change so long as they continue to flow over the rocky beds which they have cut for themselves in the flanks of the mountains, or so long as they move through the soils which are little more than the pulverized rock on which they lie. This, however, is no longer true when they issue from the mountains and enter the plains.

We think of water flowing in a stream as being the same water that it was at its source. In a certain sense it may be, but if we apply this to mean that the water in our streams after they

have issued from the mountains is the same in the quantity and character of the salts that it holds in solution as before, we err and are confronted by a series of facts that prove us to be in error. There may be occasions when the pure waters of the mountains are carried further down their course before they suffer changes than under normal conditions, but that they subsequently fall a prey to the general lot is beyond question.

If flood conditions prevail and the level of the water in the stream is higher than that of the water in the country through which it flows, in which case the velocity of the flow will also be increased, the purer, though turbid flood waters, may flow for miles further down the stream without being perceptibly changed than is the case when the flow of the stream is normal. This question might be of importance and certainly would be an interesting one to study, but the writer has never had occasion to go into this detail of the study of flood waters.

If we think of the water of a stream as a body of water flowing through a channel whose sides and bottom have no influence upon the water, just as though the water were flowing onward through a flume, we misconceive the facts. The sides and bottom, or bed of the stream are not only not tight but they are in places full of water that they discharge into the river. At others they present conditions permitting water to flow from the river into the bed and so disappear. The stream may lose water by evaporation from its surface and by leakage. The latter loss is often very considerable. These facts which are common subjects of discussion in our state suggest sufficient causes for the changes in the waters of our streams upon their issuing from the mountains into the plains. Our climate is comparatively dry but our soils are not devoid of water. The fourteen and one-half inches of rainfall may largely run off, and some of it be lost by evaporation from the surface. There is, however, a sufficient supply stored in the soils, valleys, and the marginal territory of streams to supply enough water differing wholly in character from that of the mountain streams, to modify the composition of the latter and to perceptibly change its character very soon after, if not immediately upon its leaving the mountains.

The mountain masses represent very old rocks which have been changed into schists and granites. Lapping upon the flanks of these are younger and different rocks, some of the latter being made up of fragments of the former. The water gathered within the mountains carries some mineral matter that dissolves out of the rocks, but this amount is not great and its character is very uniform throughout this section. The amount and character of the mineral matter is rather a benefit than a detriment to the water, it not being sufficient to change its character as soft water.

Upon its entering the plains it begins to receive an increased amount of mineral matter and we soon find from four to more than seventy times as much and the water passes from a soft, mountain water to a hard, alkali, plains water. This change can be detected within a short distance of the point where the streams leave the mountains.

The water then that we use for irrigation rarely has the same purity that it possessed in the mountains. In one experiment I found that in flowing about ten miles through a ditch, the mineral matter carried by the water increased fivefold. This mineral matter came, of course, from the land adjacent to the ditch.

In our natural waters, those of our mountains, it is proper and in perfect accord with what we would expect, that they should contain corbonate of lime, magnesia, etc. and we find such to be the fact, but as soon as they pass into the plains section of the stream they begin to exchange these for the sulfates until these latter become the predominating salts. In the meantime the three grains per gallon in the mountain water have become 100 grains per gallon in the plains water. This is not an exaggerated statement, but one far within the limits of fact. The water of the Cache la Poudre carries in the mountain sections of its course 2.9 grains of mineral matter per gallon, and just above Greeley, 115 grains, the carbonates constitute nearly 40 per cent of the former while magnesia sulfate, Epsom salts, constitute nearly one-third of the latter. Almost the same statement can be made of the Arkansas, at Canon City, the river water carries say 10 grains per gallon, below Rockyford 156 grains. The carbonates constitute 50 per cent. of the former while Glauber and Epsom salts constitute 40 per cent. of the latter.

In neither of these statements have I taken any account of the calcic sulfate. It is difficult to judge how much of this change is directly attributable to irrigation. Irrigation may exaggerate these changes but that they would take place in a large measure if there were no irrigation is indicated by the fact that they begin immediately, so far as we can see, upon the waters leaving the mountains, and also by the changes in the water in ditches above which there is but little or no irrigated land.

The cause of these changes is the entrance of water from the land adjacent to the river course, or return waters.

In order to hold the flood and other waters until they can be applied to crops and be made beneficial to the country, large reservoirs have been established and the river waters conducted into them and retained there for varying periods. These reservoir sites are depressions capable of having their holding capacity increased by embankments thrown up or built in the proper place. They

must be above the land to be irrigated and are not as a rule in low places, but they are natural collecting basins, many of them having been small lakes before they were converted into reservoirs. These conditions suggest that they might now receive larger quantities of seepage water which in some instances is undoubtedly the case.

These stored waters sometimes suffer as great changes as the river water. It is understood that the water stored is taken from the river, much of it directly and some of it, the seepage water, indirectly in that this water has been taken from the river, applied in irrigating land and has reappeared as seepage water. A small portion has fallen as snow or rainwater.

In studying the changes in the reservoir waters it is not easy to determine just how much is to be attributed to the several causes contributing to them. If the waters were found to be quite pure, with an increase of only 0.5 of a grain per gallon, the gain could justly be attributed to evaporation from the surface of the reservoir. This would be the exact amount in the case of Terry lake. But we find an increase in this instance of upwards of 130 grains per gallon instead of 0.5 of a grain and the amount of salts indicated by this small amount, 0.5 grain per gallon, can be wholly neglected without affecting our final results in the least. The only rational explanation that we can offer for this increase is the seepage, together with whatever quantity of soluble salts may be furnished by the bed of the reservoir.

The amount of salts actually present in some of these reservoirs is rather surprising to the layman, and to others too, who are not cognizant of the facts in the case.

In the instance of Terry lake, which presents the most striking results of the four reservoirs which I have studied in anything like detail, the amount of salts held in solution was in round numbers 27,000 tons. The samples on which this estimate is based were taken just before they began to draw off the water and I think were as good as could be gotten. A volume of Poudre river water equal to the content of Terry lake, 9,000 acre-feet, would contain about 500 tons of mineral matter, leaving 26,500 tons as having been brought in by seepage. The other lakes, reservoirs, examined gave smaller figures but indicate the same general fact.

A peculiar fact is that there was a slight increase in the percentage of potash which, for reasons that would take too much space to enter into in this place, we believe to indicate that much of this increase was due to the solution of alkalies by waters flowing over the surface of seeped ground.

The changes which took place in this instance are so patent that they cannot be misinterpreted; the carbonates, relatively

abundant in the residue from the river water, have almost disappeared, and we have in their stead sulfates, Glauber and Epsom salts forming 65 per cent. of the total mass. All the reservoir waters studied show the same changes, but Terry lake alone shows it in this extreme degree. Windsor reservoir, however, shows it in a very high degree, only a little less than Terry lake.

The water that is applied to the land then can be said to be of two classes, river water taken for direct irrigation and such as has been stored. Of late years measures have been taken to utilize waste and seepage water wherever available. This may differ a little from the stored water but so far as my knowledge goes it is seldom more heavily laden with mineral matter than the water of Terry lake and we need not consider it as making a separate class.

The amount of mineral substances carried by the river water before it leaves the mountains, which is available as plant food, is very small, 6.25 pounds of potash per acre-foot and the amount of other salts added with such water is of no moment either way. But the water taken for direct irrigation seldom reaches its destination without receiving a decided addition to its stock of mineral matter and a considerable increase in the potassic oxid carried by it. As the question considered relates to the land to which the water is applied, the source from which the potash is obtained is not considered but simply the fact that it is contained in the water as applied to the soil. The amount of potash in the river water ,as distributed on the field, was greater than we have found it to contain as mountain water, almost twice as much, but it was not a large quantity, only 11.6 pounds per acre-foot. This water as a fertilizer was not of much value. It may have been worth 50 cents per acre-foot. Neither did it carry salts which in any reasonable quantities would prove deleterious. The benefit derived from the application of this water is from the application of the water as such and not from any mineral matter held in solution.

The value added to this water by the presence of organic matter and any nitrogen contained in it is also very small, in fact as good as nothing, between 60 and 70 cents per acre-foot. While we do not add any considerable quantity of directly fertilizing salts there is nothing added in sufficient quantities to diminish in the least the good that it does. Is the same the case with stored waters? We can give only a tentative answer to this question. Our soils contain soluble salts whose influence upon our crops is, to say the least, of doubtful benefit, and to add more of the same sort would not seem to be very wise. We have given the capacity of Terry lake as 9,000 acre-feet and its content of salts as 27,000 tons, all of which is distributed with the water, or allowing one

foot of water per acre it would add three tons, 6,000 pounds, of these salts. If the potash contained in this quantity of salts were present as sulfates, it would weigh 27 pounds. The remaining salts, 5,973 pounds, are either indifferent or when present in large quantities, undesirable. I have used Terry lake as an example in order to present the question which, as every one will see, is further raised by the use of seepage water.

If these salts are not deposited on or in the soil the question relative to their influence is reduced to one relative to their immediate effect upon the plants.

The salts present in Terry and Windsor lakes are calcic, magnesic and sodic sulfates with very little carbonate, probably sodic carbonate. These two lakes or reservoirs probably represent the greater part of the stored water used for irrigation and the rest will be represented by Long Pond and Warren lake water, which carries relatively more sodic carbonate and less sodic sulfate.

The seepage water that I have examined has varied considerably, a result which was to be expected, but the general composition of the mineral matter held in solution by these waters is fairly represented by the salts found in the stored water. The seepage water in sections where irrigation is not general and the supply of water not abundant, is heavily charged with salts, calcic, magnesic and sodic sulfates, the last being strongly predominant. On the other hand samples collected under different conditions have been found to carry smaller amounts of soluble salts in solution than some of the stored waters, and the salts present were calcic and magnesic sulfates together with carbonate, probably sodic carbonate. These statements are sufficient to set forth the composition of these waters and their similarity in a very rough and general way.

General statements are to be found of the effects of these salts on plants, but it would be more satisfactory if we had series of experiments giving us, conclusive results as to their detrimental or perhaps beneficial effects, when present in known proportions. This question is of interest to us and may become more so, but it has not been of such general interest as to lead to the making of tedious experiments to determine it. The tolerance of these salts by ordinary plants, sodic carbonate excepted, is probably far beyond the limit to which they are at all likely to accumulate in our soils.

The samples of soils which I have found to be richest in alkali salts yielded upon extraction a little less than 4 per cent. This was beyond the limit at which we successfully cultivated plants but we succeeded in soil, the surface portion of which showed one-half this amount or 2.0 per cent., but taking the first four inches of soil there was only 1.4 per cent. The salts found in

this case were calcic, magnesic and sodic sulfates principally. The distribution of salts in the soil has an important bearing upon this question. These observations were not the results of prearranged experiments but indicate just as certainly as though they were, that large quantities of these salts may be present in the soils, other conditions being favorable, without precluding successful cropping.

If these figures be nearly correct, we can have in the first foot of soil as much as 25 tons, but probably not more than 50 tons of these salts, the mechanical condition of the soil and the drainage being good, before the salts become decidedly injurious. Accepting this maximum which is tentatively given as approximately correct, and based upon a limited experience, we may get a clearer view of the importance of this question. Taking a water as rich in mineral matter as Terry lake water, carrying three tons of salts in each acre-foot, we see that the application of nine acre-feet would add an amount of salts in excess of our lower limit. These salts would have been applied at the surface of the soil in nine successive portions, and unless it were carried down into the soil with the water, would already appear as an incrustation, especially under favorable weather conditions.

There is no doubt but that the soil does, as it were, strain out some of these salts, but it takes a thick layer to accomplish this. It would be difficult to explain how this is done but the soil particles hold on to these salts in some way and do not permit all of them to pass through the soil with perfect freedom. Indeed it is not probable that it permits any of them to pass through with perfect freedom but it retards some more than it does others. These salts are not collected within the first foot of soil, nor within the second, but may pass down several feet before they are stopped, so that, while there may be an addition of these salts held in solution in the water, as there evidently is, the addition is not necessarily to the surface soil, though the water is applied there. There is another thing that helps us in this case. The soil selects the salts which it retains and it seems to permit the most dangerous ones to pass through it more readily than some others. The ratios of the salts in solution in the water as it is put onto the ground, while it is in the ground, and as it flows out of the ground, are not the same. We cannot attempt to discuss this subject. The following statement is by no means perfectly accurate but it will serve roughly to show how the sodic carbonate, for instance, is permitted to pass through the soil more readily than the sulfate.

In an experiment which we made we found that an acre-foot of irrigation water contained 438 pounds of sodic carbonate, the water in the soil at a depth of from two to four feet contained 543

pounds and a like quantity, an acre-foot, of drain water contained 895 pounds. The water in the ground contained 868 pounds of sodic sulfate while drain water contained 168 pounds in an acre-foot, Evidently the sodic carbonate has passed out of the soil much more freely than the sulfate. If the sodic carborate were retained unchanged by the soil the result would be most unfortunate. This sodic carbonate is none other than "black alkali." We will take an irrigation water, such as we found that of Warren's lake to be in 1902, an excellent irrigation water with only 26 grains of mineral matter in each imperial gallon. We find in this 88 pounds of sodic carbonate per acre-foot, or the application of 20 acre-feet would add 1700 pounds of anhydrous sodic carbonate to each acre of land. Experiments made some years ago led me to conclude that if there were as much as 1750 pounds of sodic carbonate per acre, taken to a depth of one foot, it would under ordinary conditions kill young plants such as beets, etc. If the soil retained the sodic carbonate within a foot of the surface without changing it in any way the result would be that the soil would be rendered perfectly useless. The soil fortunately does not retain this, the most dangerous of alkali salts, but permits its passage rather readily, and its eventual removal by the drain water.

These properties of the soil fortunately prevent to a great measure, the accumulation of the more injurious salts added with the application of seepage water, or such as have been stored and become more or less heavily charged with soluble salts.

The water used for direct irrigation, that is, water taken directly from mountain streams does not carry any notable quantity of plant food. Water that has been stored in reservoirs, especially such as receive off-flow, waste and drainage waters, may carry more potash, but with it a very large amount of other salts. These salts are not very intense in their action on vegetation and are disseminated through a very large mass of soil and the most injurious one of them, sodic carbonate, is not retained by the soil. In other words, is rather readily permitted to pass into the ground water and thence into the drain waters, if drains have been established.

The changes effected by the irrigation water after it has entered the soil and before it sinks below the reach of the plants or passes out of the soil, present an interesting subject of study. The general and important question in this connection is, how efficient an agent it is in bringing plant food into an available form. Perhaps an equally important question is, what part does it play in changing deleterious salts into less injurious ones or in removing them from the soil. These questions are much more easily suggested than answered. It is conceded that food to be available to plants must be soluble. It, however, does not necessarily fol-

low that it must be present in the soil in an ordinary aqueous solution. But when present as such it is capable of being taken up by the plants. The most important mineral substances that the plants need are potash, lime, phosphoric acid, chlorin, sulfur etc. The one used in the largest quantity by them is potash. The total quantity of this substance in our average good soil is probably not far from 40 tons to the acre taken to the depth of one foot; the percentage of this available is small and the form in which the available portion is present is doubtful. The rest is present principally as a felspar. It has long been known that the water attacks this mineral and I have shown that the oat plant can obtain potash from it if it has been finely powdered. The question whether the water in the soil dissolves this element of plant food out of the felspar is important. While we can argue that it must do so we want to know that it does, and how fast. We can not always obtain all the information that we desire but we have tried to find out how much potash was present as a free solution in the soil, or better, how much potash was contained in this water after it had entered the soil. An acre-foot of water, as applied to the field, contained almost 12 pounds of potash. A like amount of water as it was found in the soil after irrigation contained 18 pounds, a definite gain of six pounds per acre-foot of water. This is not a large amount of potash to be gathered by this amount of water but it serves to show positively that work is being done by this water, for it is richer by six pounds of potash than it was before. This problem is not so simple as it seems and there is much more involved in it than is here stated. But the fact as here stated is near the truth in spite of the many things that are left out of consideration. There is in it an abundance of chlorids and sulfur as sulfates to supply the plants with these elements.

I have not been able to find that it plays any direct part in supplying the plants with phosphoric acid. These statements show that the water within the soil is an active agent working constantly in behalf of the plants, but there is other work that it does, likewise beneficial to the plant but less directly so.

The water brings potash into solution within the soil but owing to certain properties of the soil particles it is not able to carry it out except in smaller quantities. I have tried to show that the water draining out of the soil carried the sodic carbonate out more readily than it does the sulfate, and I will now add that it seems still more difficult for it to carry out the potash. We have stated that the irrigation water carried 12 pounds potash per acre-foot and the ground water 18 pounds, taking the average of a good many ground waters we get 20 pounds per acre-foot. The drain waters carry only about five pounds per acre foot. The

water then leaves the potash in the soil. I cannot give the ratios between the water applied, the water in the soil and the amount of drainage. It would be much more satisfactory if I could, but we will have to content ourselves with comparing like volumes of water, the acre-foot.

Another question suggests itself. What are these waters doing for us in regard to the salts that we do not want, beside the sodic carbonate which we have seen that they are removing? Their work in this line may be disappointing but still they are efficient and constant friends. We have seen that the water of one of our reservoirs, Terry lake, contained three tons of mineral matter per acre-foot; and we find that an acre-foot of drainage water which came from a pretty bad piece of land, carried July 23, 1900, 2,840 pounds, a little less than half as much as the stored water and very much less than the water within the soil, either after or before irrigation. It is evident that the salts do not pass out of the soil into the drain water as easily as we would expect and yet they carry a large quantity when we calculate it for a year.

The salts that the drain waters carry will vary some with the soil, but in our case we find them much more uniform than the salts carried by the waters while in the ground itself. The salts that we find in these waters are calcic sulfate, magnesic sulfate and the next one in the order of the quantity present is usually sodic carbonate. We have observed one instance in which the quantity of sodic sulfate present was greater than that of the sodic carbonate, but in this neither of these salts were present in large quantities. There was more sodic sulfate present in this sample, and much less sodic carbonate, than is usually found in drain waters.

The salt removed in the largest quantity was found to be calcic sulfate. There is an abundance of this salt in the soil and under our conditions I imagine that it is a matter of indifference whether it is removed or not. The magnesia salts which came next in quantity in the drain waters also occurred abundantly in the soils, especially in those parts of our fields that were in the worst condition. I do not know whether these salts have any part in determining the mechanical condition of the soil or not, it is quite possible that they have, but I am unable to suggest just what that part may be. The presence of magnesic salts in very large quantities in certain ground waters, together with the fact that they are uniformly present, suggest that the series of changes taking place within the soil may end in the elimination of magnesic salts. I thought for a time that we might be able to find still other facts to support this suggestion, perhaps demonstrate that these salts are the last products in the series, but I have not found them and the suggestion seems of doubtful value.

The two most direct services rendered by the drains are, first, the removal of surplus water; second, the elimination of sodic carbonate from the soil. The scope of this bulletin will not permit any further discussion of these subjects, besides we are convinced that the facts are more important than any attempt to explain them would be.

Repeated examinations have failed to show the presence of more than traces of phosphoric acid in the drain and ground waters. This is in marked contrast with the aqueous extracts of some of the soils. The importance of this is that this very valuable, and for our soils particularly desirable substance, is held pretty firmly within the soil, and though the other salts are involved in probably many changes of solution, this substance remains held by the soil particles and is given up under the influence of the plant whose needs it is to supply. How it is held, I do not pretend to say, but we know that it must be retained in some way, for we know that carbonated waters will extract it from the rocks in which it occurs. Phosphoric acid occurs in the soil in which there is both water and carbonic acid, and yet the water within the soil and that which drains out of it carry no more than traces of it.

The exhaustion of the fertility of our soils by the drain waters proceeds then very slowly, so far as the potash and the phosphoric acid is concerned. The former is removed by these means more rapidly than the latter, both in absolute and relative quantities. An acre of good soil taken to a depth of one foot contains about 78,750 pounds of potash and about 9,000 pounds of phosphoric acid. The drain waters contain easily determinable quantities of potash and only traces of phosphoric acid, for the detection of which we have to use large quantities of water or the residues representing it. If we should take a larger quantity of felspar which occurs in these soils, grind and treat it with water and carbonic acid, we could find upon examining the water, after it had been in contact with the felspar for a few days, that it contained easily determinable quantities of phosphoric acid. Why then do the ground and drain waters contain none or only a trace of it? We answer this question by appealing to the observed property of the soil particles in mass to retain certain salts, which we have seen illustrated in a very marked degree in the case of sodic sulfate which we found present in the ground water of the soil in large quantities, but as good as absent or wholly so in the drain waters.

The claim often presented, that we add a significant quantity of fertilizing ingredients with our irrigation waters, cannot be seriously urged for them. Almost the only good they do is in supplying moisture to the plants. Even such waters as have been

stored and have become heavily laden with salts by seepage or solution carry comparatively little of either the potash or nitrogen that is needed by our soils.

Nothing has been said about this latter element, concerning which it is customary to say a great deal. The reason for this is that neither the irrigation, nor ground, nor drain waters showed a content of nitrogen which justified any special notice. There is still another point frequently mentioned in connection with irrigation waters which we will notice a little more fully, i. e., that they fertilize the soil by means of suspended matter which they carry. This point is not in the least applicable to stored waters which remain stored from one to twelve months and sometimes still longer, during which time they would deposit their suspended matter if they ever carried any. This suspended matter tends to silt up the reservoirs which process is evidently proceeding very slowly. The question relative to the value of the suspended matter applies then to water used for direct irrigation and to flood waters. This question, too, is of varying importance according as the streams had in view are mountain streams, whose courses are through massive and metamorphic rocks, as is the case with the upper portions of our rivers, or whether they are plains streams, having their courses through sections of sedimentary material which is easily torn loose by heavy rains and currents. If the section of country through which the rivers run is subject to visitations by torrential rains, the river waters may at such times carry very large amounts of suspended matter. Such conditions do not prevail in this section of Colorado. We occasionally have torrential rains and the river waters may be black or red with mud, according to the character of the country in which the rains fall. But such conditions are of short duration. The period of high water is due to the melting of snow in the high mountains. The water of this season is, it is true, more turbid than during times of low water, times of heavy rain or flood excepted. The amount of suspended matter during this time of high water is insignificant in quantity. I have made observations to establish the amount and found it to be only 0.0016 per cent. of the weight of the water, or about forty-four pounds per acre-foot of water If this sediment were never so rich it would amount to but little as a means of fertilizing our soils. It is no more important from the standpoint of its quality than it is from that of its quantity. It contains just about the same percentage of potash that the soil itself contains and it is even less available if there is any difference at all. The value of this suspended matter is less than I expected to find it.

It is seldom that our waters carry large amounts of suspended matter due to heavy rains, but occasionally they do. On an

occasion when the Poudre river was very high and was carrying limbs, stumps, trunks of trees, etc., I had a sample of its water taken to determine the amount and composition of sediment that it would yield. I found that it yielded 0.213 per cent. of its weight. This was a surprising result for one would have judged it to have held much more matter suspended in it than is here designated. The compositon of this suspended matter was quite as much a matter of surprise, for except in moisture and organic matter it was not very unlike the soil to which it would have been applied if used for irrigation.

The results of these examinations may surprise the reader but I am convinced that the facts are as these examinations show, i. e., that the sediments carried by the waters are small in amount and so similar to the soils in composition that they cannot be considered of such benefit as to make their application a matter to be sought after.

This view was more than sustained by the examination of a silt taken from a reservoir filled with flood water from the Arkansas river, which carried less phosphoric acid, potash, and nitrogen than our average quality of soil contains.

Bulletin 84. **October, 1903.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

An Apricot Blight.

—BY—

WENDELL PADDOCK.

PUBLISHED BY THE EXPERIMENT STATION,
Fort Collins, Colorado.
1903.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

Executive Committee in Charge.

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PLATE I. Apricot Fruit Attacked by Pear Blight. Photographed June 25.

An Apricot Blight.

By Wendell Paddock.

The writer's attention was called to a disease of apricots in the fall of 1902 by Mr. H. E. Mathews, horticultural inspector of Delta county, which was thought by the growers to be an attack of pear blight. Many of the twigs had blighted and all of the fruit on several of the trees had decayed. At the time of my visit it was too late in the season to see the disease in an active condition, but microscopic examination of the dead twigs and of the dried fruit failed to show any sign of fungous attack. The indications pointed to a bacterial disease but the idea that it was caused by the germs of pear blight was doubted since at that time there was no record of this disease ever having attacked the stone fruits.

The orchard was visited again on June 25, 1903, when the disease was found in an active condition. In one row, containing ten Moorpark and ten Royal apricot trees, every tree was more or less affected, as well as other trees in various parts of the orchard.

At this time many of the fruits were attacked, the diseased areas varying in size from a spot an eighth of an inch in diameter to irregular areas that involved three-fourths of the fruit. The skin over these places soon became nearly black in color and shrunken as the tissues were consumed till the outline of the pit was disclosed. These discolored areas were always definitely outlined and bordered with a zone of watery appearing tissue usually about an eighth of an inch in width. The latter was green in color and as hard as the sound flesh. Three such fruits are shown on Plate I.

The smaller spots where the disease had evidently just started, invariably surrounded a lenticle, thus indicating that the disease gained entrance to the fruit through these openings.

The injury to the twigs may be described best by saying, that they resembled closely, blighting pear or apple twigs. (Plate II.) So far as noticed only tender twigs of the current season's growth were attacked. These were shrivelled and discolored from a few to several inches of their length and small drops of sticky fluid were occasionally found on their surface and upon the

shrivelling leaf-stems. The discolored outer bark blended gradually into normal appearing tissue but the inner bark was discolored for some distance below any external evidence of disease.

Unfortunately the infected orchard is so far from the Experiment Station that the progress of the disease could not be watched, but specimens of diseased ripe fruit were secured from Mr. Mathews on August 2. These were in all stages of decay. Those that were only slightly attacked had a small shrunken area over which the skin was discolored but little. In those specimens where a half or two-thirds of the fruit was involved the tissue was much shrunken and the skin over these areas was quite brown. In some specimens a thick juice, swarming with bacteria, oozed from the diseased tissue and collected in a large drop on the surface. Much watery appearing tissue which was still firm surrounded the diseased parts.

Infection evidently took place more readily early in the season as there was much more diseased fruit at the time of my visit than there was when the later specimens were secured.

Since the appearance of Prof. Jones' paper* in which he proves that pear blight may produce twig blight in various kinds of plum trees it seems probable that this blight and rot of the apricot was due to the same organism. The trees are situated in a mixed orchard and the adjacent pear and apple trees suffered severely from an outbreak of pear blight during the season of 1902, and it was abundant, though not as severe, in 1903. Microscopical examination showed that the diseased parts of both twigs and fruit were swarming with bacteria and that these germs were abundant in the watery appearing though firm flesh of the fruits.

FIG. 1. Apple three days after inoculating with diseased tissue from an apricot fruit.

Working upon this supposition experiments were undertaken as follows: June 30, 12 apples were inoculated by inserting under the skin bits of the watery tissue taken from diseased apricot fruits. These wounds were covered at once with sterile grafting wax. Four of the apples were picked by children but at the end of twelve days the remaining eight were found to have developed the rot that is peculiar to apples attacked by pear blight. The disease gradually spread until the entire apple was discolored and shriveled and drops of sticky fluid appeared upon the surface of most of them. (Fig. 2.)

*Jones, L. R. Studies Upon Plum Blight. Centralb. f. Parasitenk. u. Infek. II. Abt. II. Band. pp. 835-841.

Nine apple twigs were inoculated on the same day with the fresh diseased tissue from apricot fruits. The disease spread in all of these twigs, killing them from the tips down; in one instance ten inches of the twig from the tip, back, was dead. No difference could be detected in the appearance of these twigs and in those that were known to have been killed by pear blight. Both leaves and twigs shrivelled and turned dark colored and drops of sticky fluid exuded from the bark and from the leaf stems.

On the same day, June 30, seven apple twigs were inoculated with fresh diseased tissue taken from a blighting apple limb. These inoculations were made for the purpose of comparing the disease produced with that produced with germs taken from apricot fruits. All of the twigs developed typical cases of pear blight, becoming shrivelled, dark colored and exuding drops of sticky fluid. The twigs in this lot could not be told from those that had been killed by inoculating with diseased tissue from an apricot fruit. The bacteria appeared to be the same when examined with a microscope and made the same growth when cultivated artifically in the laboratory.

FIG. 2. Apple inoculated with tissue from apricot twig; the latter having been inoculated with a culture of pear blight.

There was no blight in the trees on which these experiments were made and to make sure that the mechanical injury of inoculation could not cause the twigs to die or the fruit to decay, control or check twigs and apples were carried along with all the experiments. These were made by making incisions with a sterile knife through the skin of the apple or through the bark of the twigs; the wounds were then covered with sterilized grafting wax. No disease developed in any of the checks and the injuries soon healed.

These experiments were repeated a number of times with cultures of the bacteria taken from apple twigs, apricot twigs and apricot fruits. Inoculations were made in both apple twigs and fruit and the results were the same, namely, a typical case of pear blight from all three sources.

As there are no apricot trees growing on the College grounds, Mr. J. S. McClelland kindly offered the use of one of his trees for experimental purposes. A number of inoculations were made in the twigs of this tree July 8. Cultures of the disease obtained from apple twigs, apricot twigs and apricot fruit were used. The orchard was visited on July 20 when it was found that blight had been produced in a number of the inoculated twigs, while the check twigs remained sound.

The disease was recovered in pure cultures from these apricot twigs in which blight had been artificially produced and apples inoculated with this material developed typical cases of pear blight. (Fig. 2).

The results of these experiments prove that pear blight may attack apricot twigs and fruit and observations show that the disease may do a considerable amount of damage. While this apricot blight has not yet assumed alarming proportions, yet there is a possibility of its becoming a common disease. It has been found in several Colorado orchards and an apricot disease has been reported from Utah, which is probably due to the same cause. Blighted twigs were also found on Prunus simonii trees which were also thought to be caused by an attack of pear blight.

REMEDIES.

Since this disease has been proven to be due to attacks of pear blight, the logical method of treatment would appear to be the suppression of this disease in apple and pear trees. With pear and apple orchards free from blight there would probably be no apricot blight. There is little probability at present, however, of ever attaining this ideal condition, but much can be done to hold the disease in check if all orchardists will unite in following the best treatment that is now known. This consists in cutting out all blighted limbs after the growing season is over, as in late fall or any time during the winter.

It is now definitely known that the germs of pear blight live over winter in occasional diseased limbs. The germs in such limbs become active in the spring with the growth of the tree and cause a thick fluid to ooze from the diseased bark. This juice is swarming with blight germs and because it is slightly sweet, bees and other insects are frequently attracted to it. That bees do carry blight germs in particles of this sticky juice that may accidently stick to their bodies was proven by Mr. Waite of the Department of Agriculture. Then when visiting flowers in their search for nectar or pollen it is easy to conceive how these particles may become dislodged from the bees' bodies and fall into the nectar in the blossom. Mr. Waite also proved that this does take place as he found pear blight germs growing in nectar in pear flowers. Thus the pear blossoms become sources of infection and the disease spreads rapidly or "like a fire," from which expression the term "fire blight" is derived, as hundreds of insects visit flower after flower.

Just how many of the twigs become infected has not been satisfactorily explained, but in the light of our present knowledge

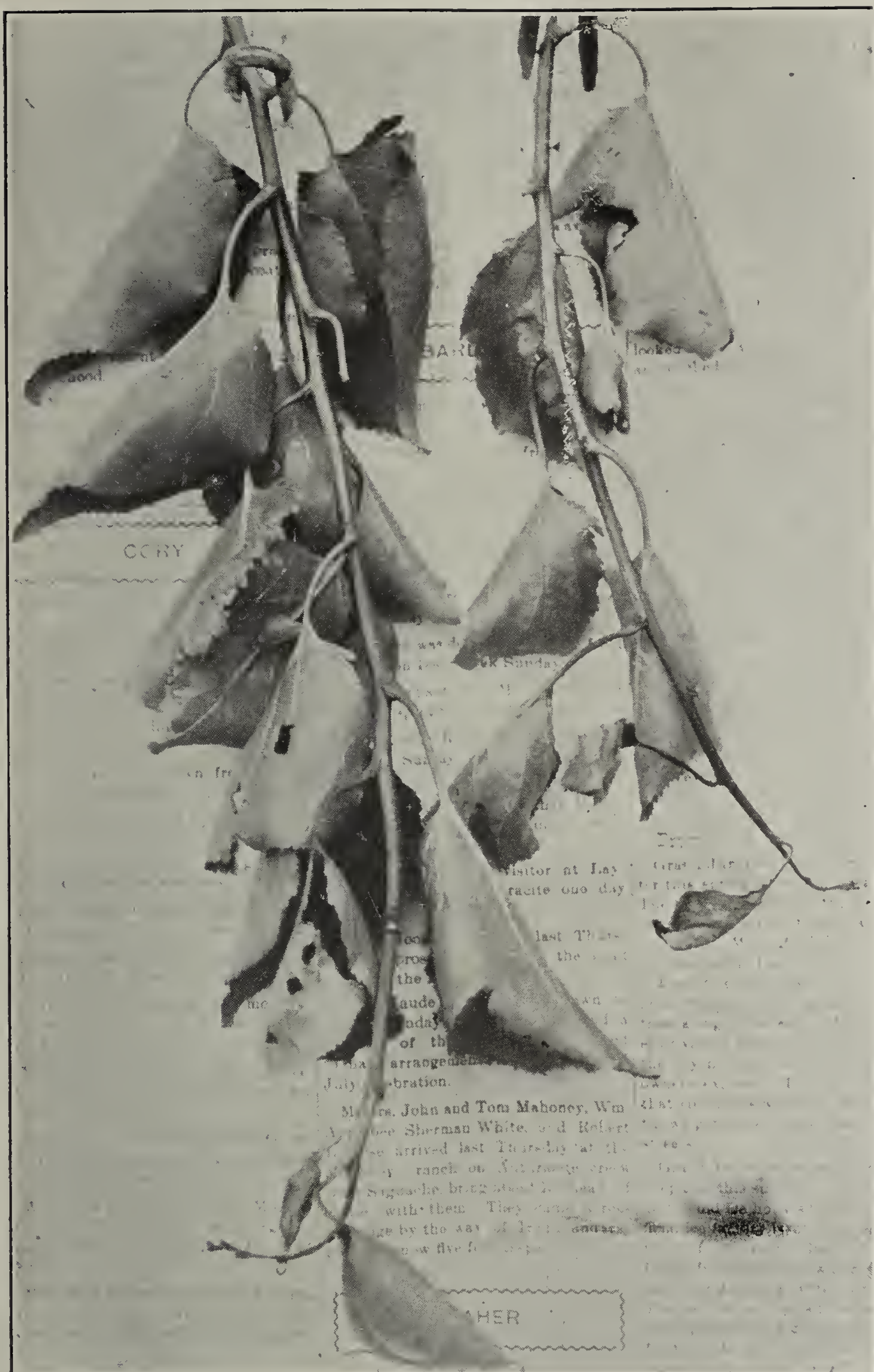


PLATE II. Apricot Twigs Attacked by Pear Blight.
Photographed June 25.

the cases of so-called "hold-over" blight in limbs and twigs must be regarded as the sole means of keeping the disease alive over winter. The appearance of this apricot blight then should emphasize the importance of keeping pear blight in check. All diseased trees whether they be apple, pear, apricot or plum, should be looked over carefully in late fall or during the winter and all blighted limbs and twigs removed. When cutting out diseased branches, especially during the growing season, care should be taken to make the cut 8 or 10 inches below any evidence of discolored bark.

DETAIL OF EXPERIMENTS.

Experiment No. 1. June 30; inoculated 12 apples with diseased tissue from apricot fruits. Apples on the tree and about one-fourth grown. Inoculations made with sterile instruments and diseased tissue taken from in under the skin from the zone of watery appearing tissue. The wounds were covered with sterile grafting wax as soon as the inoculations were made. Notes were taken on the development of the disease as follows:

July 7. Inoculations have taken in four fruits. In one, disease has spread over one-fourth of the surface and a characteristic bead-like drop has formed on the surface. Four fruits destroyed by children. The other four show no signs of disease. July 11. Inoculations have taken in all of the apples.

These apples were eventually entirely consumed by the disease. Five check apples punctured but not inoculated remained sound.

Experiment No. 2. On the same date, June 30, nine apple twigs in the same tree were inoculated with diseased tissue from apricot fruits as described above. All wounds were protected with sterile grafting wax.

July 7. Blight appearing on all of the twigs. Twigs brown and whithering with bead like droplets on surface. July 31, disease has spread 10 inches on one twig and eight inches on another.

Experiment No. 3. For the purpose of comparison seven twigs were inoculated June 30 with diseased tissue from a blighting apple limb. Bits of inner bark which was only slightly discolored by the disease were inserted in incisions made in the tips of green twigs.

July 7. Three twigs show no results. Four are diseased and show characteristic symptoms of pear blight, though the disease has not advanced as rapidly as it did in the twigs that were inoculated with tissue from apricot fruits.

July 11. All the twigs in this experiment are now blighting and thick juice has formed in drops on the surface as in the other experiment. The gross appearance of the twigs in the two lots are the same and microscopical examination shows that all diseased parts in both experiments are swarming with bac-

teria which appear identical. Eight check twigs punctured at the tip with a sterile knife show no sign of disease.

Pure cultures of the bacteria from the three sources, apricot fruits, apricot twigs and apple twigs were secured as soon as possible with which further inoculations were made. Plain neutral potato agar was used in making poured plates from which transfers were made to tubes of potato agar, potato plugs and sugar beet plugs. Inoculations were made July 7 with the pure cultures into apple fruits and apple twigs as given in the following tables:

TABLE I.

Inoculations of Apples with Cultures of Bacteria Secured from Diseased Apricot Twigs, Apricot Fruit and Apple Twigs.

No. of Experiment.	No. of Apples.	Sources of Cultures.	Date of Inoculation.	Date of Examination.	Results.
No. 4........	5	Apricot Twigs	July 7	July 28	All discolored and shrivelled.
No. 5........	5	Apricot Fruit	July 7	July 14	Negative.
No. 6	6	Apple Twigs	July 7	July 28	One fruit black and shrivelled.
No. 7	6	Check		July 28	Sound.
No. 8...	6	Apricot Fruit	July 14	July 28	Five fruits shrivelled and discolored.

Evidence of the success of the inoculations became apparent in some instances on the third day. (Fig. 1.) There being no development of disease in any of the apples in Experiment No. 5, further inoculations were undertaken on July 14, as indicated in Experiment No. 8, using another tube of the same culture. Final notes were taken on July 28. The five fruits in Experiment No. 4 inoculated with culture from apricot twigs all discolored and shrivelled. Experiment No. 5 gave negative results, probably due to weak or dead culture material. No. 6, using a culture of known pear blight taken from a blighting apple limb, one fruit black and shrivelled; the other five gave negative results. No. 7, check apples, all sound. No. 8, inoculated with culture from apricot fruit, five apples shrivelled and blackened over most of their surface. One showed no evidence of disease

TABLE II

Inoculation of Apple Twigs with Cultures of Bacteria Secured from Diseased Apricot Twigs, Apricot Fruits and Apple Twigs

No. of Experiment.	No. of Twigs.	Source of Culture.	Date of Inoculation.	Date of Examination.	Results.
No. 9..............................	7	Apricot twigs.	July 7	July 29	Five twigs diseased.
No. 10	7	Apricot fruit.	July 7	July 29	All twigs diseased.
No. 11..............................	5	Apple twigs.	July 7	July 29	All twigs diseased.
No. 12	6	Check.		July 29	Sound.

In Experiment No. 9 the disease made good growth in three twigs, extending eight inches in one. The growth was slight in two twigs while the remaining two gave negative results.

The disease made good growth in all of the twigs in Experiment No. 10; one of them being blighted for 18 inches of its length. All twigs blighted in Experiment No. 11. One diseased 18 inches of its length and others for 12 inches. The twigs used in this experiment were younger and more succulent than the others, which no doubt accounts for the greater growth. Check twigs all sound.

There being no apricot trees on the College grounds, Mr. J. S. McClelland kindly offered the use of one of his trees for experimental purposes. Accordingly inoculations were made in the twigs of this tree as shown in Table III. The tree bore no fruit this season.

TABLE III.

Inoculation of Apricot Twigs with Cultures of Bacteria Secured from Diseased Apricot Twigs, Apricot Fruit and Apple Twigs.

No. of Experiment.	No. of Twigs.	Source of Culture.	Date of Inoculation.	Date of Examination.	Results.
No. 13............	7	Apricot twig.	July 8	August 5	Three blighted; four, no results.
No. 14............	5	Apricot fruit.	July 8	August 5	All made some growth.
No. 15............	7	Apple twig.	July 8	August 5	Five blighted; two, no results.
No. 16............	7	Check.		August 5	Sound.

In Experiment No. 13, three twigs of the seven were blighted; one five inches, one eight inches and the third, 10 inches. New growth was selected for the experiments and the inoculations were made as near the tip as possible. The four twigs that gave no results made a rapid growth after inoculation, of from 18 to 20 inches. And curiously enough two of them were blighted at their tips. This can be accounted for by natural infection from the inoculated twigs as four other twigs were found on the tree that were blighted. None of the check twigs showed any evidence of blight and there was none found on the other two trees that stood within 12 feet of the tree experimented on.

All of the twigs in experiment No. 14 were diseased; the blighted areas varying from one to four inches in length.

Cultures of known pear blight were used in Experiment No. 15. Five of seven twigs were blighted, two of them for eight inches from the tip where the inoculations were made.

The disease was recovered in pure form from the inoculated apricot twigs and apples on the tree were inoculated as shown in Table IV. Specimens of diseased ripe apricots were received at about the this time, together with blighting twigs. Cultures were made from both sources and inoculations were made as is also shown in table IV.

TABLE IV.

Inoculation Experiments with Cultures of Bacteria from Various Sources.

No. of Experiment.	No. of Inoculation.	Source of Culture.	Date of Inoculation.	Date of Examination.	Results.
No. 17.........	6 Apples	Apricot twig.	July 29.	August 18.	Two fruits diseased.
No. 18.........	5 Apples	Ripe apricot fruits.	July 29.	August 18.	All diseased.
No. 19.........	4 Apples	Apricot twigs that had been inoculated with cultures from apricot twigs.	July 29.	August 18.	One fruit diseased.
No. 20..........	6 Apples	Check.		August 18.	Sound.
No. 21.........	10 Apples	Apricot twigs that had been inoculated with cultures of pear blight.	Aug. 7.	August 18.	Three fruits, decaying.
				August 30.	Three more fruits diseased.
No. 22	5 Apples	Check.		August 30.	Sound.

Cultures from apricot twigs produced decay in two fruits out of six inoculated while all inoculations with cultures from ripe apricots were successful.

One out of four inoculations was successful, where a culture from an apricot twig, from McClelland's, that had been inoculated with cultures from apricot twigs were used. As a more complete test was desirable than was afforded by No. 19, a similar experiment was undertaken in No. 21. Ten apples were inoculated with diseased tissue taken from an apricot twig that had been inoculated with a known culture of pear blight. Six of these inoculations were successful. The check apples in every instance remained sound.

Bulletin 85. **December, 1903**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

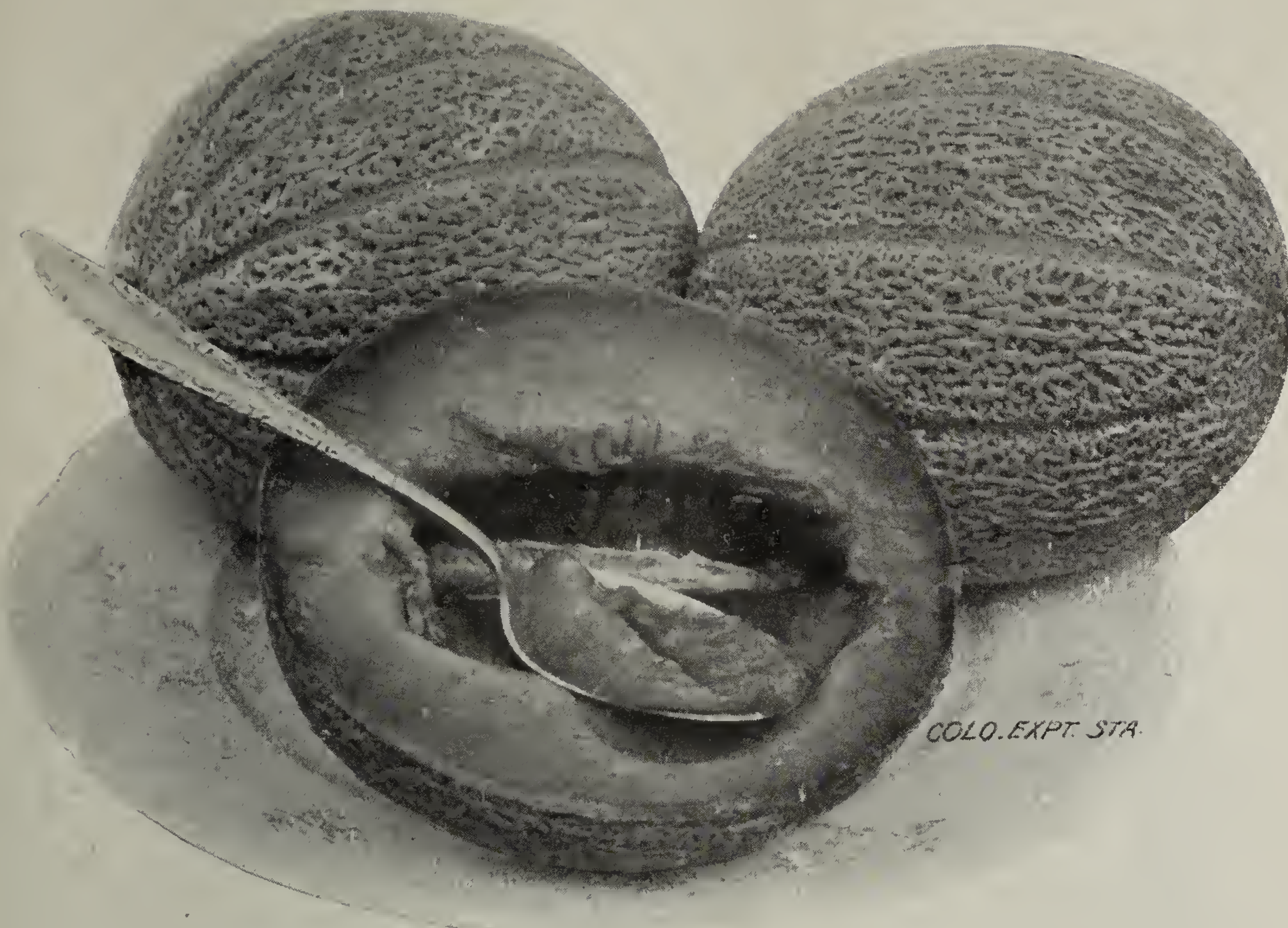
Cantaloupe Seed.

— BY —

P. K. BLINN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903

PLATE I.



Ppate II.

Plate III.

PLATE IV.

CANTALOUPE SEED.

IMPROVEMENT BY SELECTION.

BY PHILO K. BLINN.

The cantaloupe now known as the Rocky Ford was originally Burpee's Netted Gem, but under the favorable conditions which prevail in the arid regions of Colorado, it has developed into a melon surpassing in quality the parent stock, and its superior merits have won for it a new name and a popular reputation.

In the early days of the cantaloupe industry at Rocky Ford, the growers relied on Eastern seedsmen for their supply of seed, and to a certain extent had satisfactory results until the growth of the industry exceeded the supply of reliable seed, when a number of growers were supplied with seed which produced a mixed lot of varieties, wholly unfit for market as Rocky Ford cantaloupes. The loss not only fell heavily on the disappointed grower, but through the agency of bees and other insects carrying the pollen, the injury was easily transmitted to neighboring fields of choice melons, producing crosses of an undesirable nature.

On account of the introduction of these mixed strains, and the varying ideas of seed selection, the Rocky Ford cantaloupe lacks uniformity in many respects ; a large percentage of melons are unmarketable on account of size and form, which renders them unfit to crate. Defective netting and thin, soft flesh are also common imperfections. Because of these defects, the growers sustain a loss that could largely be prevented by planting a better grade of seed.

The cantaloupe is a product of years of systematic selection, and it requires the same methods to maintain its excellence as were employed in its development. Without care in selection, the natural tendency of all cultivated plants to vary will soon cause a good strain of cantaloupes to revert to an undesirable type.

There is a marked contrast between the products of carelessly selected and pedigreed, *i. e.*, carefully selected, melon seed ; the one is inclined to be irregular in size and form, with the netting thin and often wanting, and with a decided tendency to

ripen prematurely, turning yellow and soft; a loss not uncommonly of twenty to forty per cent. in culls, while choice seed produces melons that are uniform in size and shape, the netting thick and complete, the marketable stage more prolonged, and practically no loss in culls.

The wide reputation of the Rocky Ford cantaloupe has created a great demand for Rocky Ford seed, as it is claimed to produce a higher grade of cantaloupes than seed from other States, and each year large quantities are saved to fill this demand, but unfortunately for the industry, the quality of this supply is not what it should be; it is principally produced from the cull piles.

After frost, at the close of the shipping season, everything in the line of a cantaloupe, green or ripe, large or small, is gathered and run through a melon seeder, with no attempt at selection.

This seed is bought by the jobber and seedsman for ten to twenty cents per pound, and when it is on the market it cannot be distinguished from well selected seed, and doubtless is sold as such.

There would be nothing to commend such seed to any practical grower if he realized its source.

As the seed market has been so abused, to procure good seed one must either save it himself, or have seen the melons from which it was saved, or purchase it from a reliable grower before it has passed through several hands.

The fact that seed can be had cheap and growers are willing to plant it, is an evident reason for its existence on the market, but the lack of information as to what constitutes a good seed cantaloupe may also be responsible for poor seed selection. In this bulletin we wish to show what a good melon is and that it pays to plant and save good seed.

STANDARD OF PERFECTION.

The form and outward appearance of a perfect Rocky Ford cantaloupe is well represented in the several plates shown in this bulletin; as to size, it requires a melon slightly over four inches in diameter and about four and five-eighths inches long; it should have silver grey netting that stands out like thick, heavy lace, practically covering the entire melon, save the well-defined slate colored stripes; these should run the whole length of the melon clear cut as if grooved out with a round chisel, and terminating at the blossom end in a small button, well shown in the melon on the left side of Plate III. The interstices in the netting should be light olive green, that turns slightly yellow when the melon is ready for market. A melon with a black skin under the netting is not so attractive in appearance. The proper netting is well brought out in Plate I.

But the outward appearance is not the only basis for selection in saving seed ; the inside points are as essential to consider as any external quality, and no one can determine that a melon is fit for seed until it has been cut open and the inside qualities examined ; for this reason the machine seeder is of no use in selecting choice seed ; the melons should all be cut and examined by hand.

The flesh should be thick and firm, of a smooth texture, and free from watery appearance, rich and melting in flavor. The shipping and keeping qualities depend largely on the solidity of the melon, so the seed cavity should be small and perfectly filled with seed. The color of the flesh near the rind should be dark green, shading lighter toward the seed cavity, which should be salmon or orange in color. The flesh is often mottled with salmon, and not uncommonly the entire flesh is of that color. The flavor is usually quite uniform, though it is sometimes affected by the health of the vines or other conditions of growth.

The seed will bear close inspection, as it is sometimes cracked or sprouted, which renders it of no value for germination.

The first steps in seed selection should be made when the melons are growing. Extra prolific hills should be marked with stakes, and the earliest ripening specimens conforming to the above ideal should be saved as choice seed, and planted in a place isolated from other melons, and the same care should be exercised in the years that follow.

The grower can and should save his own seed, as he can give it more careful attention than any commercial seed grower.

A few growers, realizing the importance of systematic selection, have made the proper choice of seed for their own use.

As an illustration of what can be done in this line, the plates shown in this bulletin represent photographs of melons developed after five years of careful seed selection. Beginning with a melon as nearly perfect as could be found, the old saying that "like produces like" has been exemplified to a marked degree. Each year the number of perfect melons has increased, so that now, when soil, fertility and all growing conditions are favorable, the over-sized melons are eliminated ; all melons are completely netted, and practically all are marketable.

Plates II. and IV. represent an average product of the choicest of this seed.

Improvement is still possible, yet the value of careful seed selection has been so demonstrated that if melon growers would adhere to a strict selection of perfect, early-ripening melons, not only would the returns from the melon crop be increased, but the cantaloupe would become a more staple article by virtue of its improved shipping and keeping qualities.

VALUE OF CHOICE SEED.

Unless one has a well developed strain of seed, it is not probable that he can save more than one or two pounds per acre of extra selected seed, so the supply of choice seed is limited.

The market value of the cantaloupe at the time the seed is saved should determine the price of seed. Thus, it requires about as many melons to produce one pound of seed as will fill a standard crate, and actually more, because some melons need to be rejected. This cannot be fully determined until the melon is cut, when, if it proves unfit for seed, it is also lost for market. So the price of seed must be equal to or exceed the price of a crate of melons at the time the seed was saved.

During the first week or ten days of the shipping season at Rocky Ford, it is common to realize from two to six dollars per crate. No one at this time can afford to save seed to sell at the ordinary price per pound. Indeed, few growers are wise enough to save for their own use.

At the average price of cantaloupes through the shipping season, the grower must realize at least a dollar per pound to warrant him in saving seed for the market. At the close of the shipping season, when melons are no longer marketable, the seed is willingly saved for what it will bring. This is the source of a large part of the seed on the market.

The difference in value between seed saved early from perfect melons, of high market worth, and that saved six weeks later, from immature, frost-bitten melons which cannot be marketed, is not often appreciated ; yet, if the higher priced seed should yield only one or more crates per acre of early melons, or increase the total yield by several crates, which the extra vitality and superior points of perfection can easily do, the higher priced seed is cheaper at any price, and its value to the melon industry cannot be estimated.

Bulletin 86. December, 1903

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

CROWN GALL.

— BY —

WENDELL PADDOCK.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1903

PLATE I.

THE COLORADO EXPERIMENT STATION.

A Department of THE STATE AGRICULTURAL COLLEGE.
For Bulletins address the Director.

CROWN GALL.

By Wendell Paddock.

The subject of crown gall is one of vital importance in Colorado, since under our conditions the organism that is responsible for this disease of fruit trees and plants, finds congenial surroundings for growth and distribution.

The so-called galls are irregular outgrowths of tissue that commonly form around the crown of a tree just below the surface of the ground. They also occur frequently on the roots, but are quite different in appearance from the swellings that are produced by the attacks of woolly aphis, which unfortunately are also very destructive in our State.

The galls increase rapidly in size, when the conditions are favorable, and so interfere with the process of nutrition that the vigor of the tree is greatly impaired. In many instances the death of the tree is but a matter of a few years. The point of attack being underground, the infected trees are commonly unnoticed until they begin to fail. This stage may be recognized by the weak growth and yellow appearance of the foliage.

The pictures in this bulletin give a good idea of the appearance of crown gall. Plate I. shows an extreme case of the disease as affecting a six-year-old plum tree. This tree was undoubtedly attacked in the nursery, and the continued growth of the gall so interfered with its nutrition that it was able to make but a feeble growth and was nearly dead when it was dug. Plate II. is from a photograph of a peach tree, showing a large gall on the roots and a somewhat unusual case of the development of galls on the trunk above ground. Plate III. shows badly diseased apple trees just as they were received from the nursery.

This disease first began to attract the serious attention of Experiment Station workers in 1892, when the California station published a bulletin on the subject. This was followed by a number of articles from different Experiment Stations, but it was not until 1900 that any definite knowledge of the disease was gained. During this year Prof. Toumey, of the Arizona Experiment Station, published a bulletin, in which he proved that crown galls on almond, apricot and peach trees are produced by the irri-

tation of a slime mould, one of the lower forms of fungi. He was able to produce galls at will on young seedlings by inoculating them with bits of the galls, also by planting seedlings in sterile soil and then placing pieces of minced galls about their roots. Under certain conditions minute reproductive bodies are formed on the surface of the galls, which easily work their way through damp soil, or may be carried by irrigation water from tree to tree. Particles of the galls may also be carried by cultivators and other tools, so that it is easy to conceive how the disease may spread from a single infected tree to all the trees in an orchard.

Indications also point to the conclusion that the organism may remain alive for some time in decayed galls, or in galls on dead trees, or on diseased trees that have been removed from the orchard.

It is difficult to estimate the amount of damage that crown gall is responsible for, as it is a disease that is commonly overlooked, and then it is usually several years after infection that the apparent vigor of the tree is affected. Reports from a number of the County Horticultural Inspectors, as well as personal observations, show that crown gall is a common disease in Colorado. It is evident, also, from what has been said, that the effects of the disease will become more apparent as the orchards grow older.

Prof. Toumey has the following to say about the amount of damage that can be attributed to the disease:

> The seriousness of crown gall in various and widely separated portions of the country, is certainly indicative of an enormous annual loss to the fruit industry. In estimating the amount of damage done by crown gall, consideration must be given to the fact that it usually occurs underground, and is rarely seen except when the trees are taken from the nursery, or when excavations are made at the crowns. The majority of diseased trees live on year after year, but make less growth and in all probability produce less and poorer fruit than healthy trees. It is not sufficient for a tree to simply live. It must grow and ruit abundantly to be profitable. The total annual loss from this disease in this country in all probability reaches the enormous sum of from $500,000 to $1,000,000, possibly much more.

Crown gall is found on a variety of plants, including almond, apple, apricot, blackberry, cherry, chestnut, English walnut, grape, peach, pear, plum, poplar and raspberry. In the experiments above mentioned, it was found that the disease could be transferred readily from the almond to apricot and peach trees, thus indicating that the same organism is responsible for crown gall on these three hosts. Serious investigation of the galls on the other trees and plants have not yet been undertaken, but it is likely that the disease is of the same nature, if not induced by the same organism. It is to be hoped that this point may soon be established, as it is important to know, for instance, whether diseased raspberry and blackberry bushes, when planted in an orchard, may not be the means of infecting the trees, or, in the

case of a mixed orchard, the disease may not spread from stone fruits to apples and pears, or *vice versa.*

The disease does not seem to be so destructive in most sections where irrigation is not practiced, consequently many nurserymen give it no attention, or are entirely ignorant of the subject. That crown gall is abundant in such nursery districts is proven by the fact that but few shipments of nursery stock are ever received from points outside of the State that are entirely free from the disease. One County Horticultural Inspector destroyed two car-loads of trees in one season, largely because they were infected with crown gall. Most of our inspectors are equally rigid in their examinations, but it is impossible to detect all diseased trees, especially where the disease has just started.

Prof. Toumey goes so far as to say:

> Every tree that comes from an infested nursery is dangerous, and when such trees are planted, great chances are taken.

And again:

> If bundles of trees are received having a few with galls upon them, it is not safe to simply throw out the visibly diseased ones. There is no reason why the remainder of the bundle should not have the infection upon them from contact with diseased trees, and the whole should be destroyed.

The following extract from Bulletin No. 191 of the State Experiment Station of New York, may be taken as representing the general attitude of nurserymen toward the disease:

> We find crown gall not uncommon in the nurseries in western New York, but we know of no case where it has caused material loss. * * * Usually nurserymen discard the worst affected trees.

So long as the disease is not serious in their own locality, the nurserymen see no reason why they should go to the expense and trouble necessary to eradicate it, consequently the disease has spread, gradually, until it is quite common in many of the nursery districts.

The Experiment Station occasionally receives letters from nurserymen protesting against the destruction of their stock. One firm thought that fraud was being practiced when their trees were rejected, as they had never heard of this disease. Another nurseryman sent 100 high priced trees to the Experiment Station which were all condemned by the Inspector. This gentleman claimed that the galls, many of which were as large as one's fist (Plate III.), were due to a characteristic varietal growth, and not to a disease.

The best remedy for most plant diseases is preventative rather than curative, therefore the best line of treatment for crown gall would be, first of all, to buy nursery stock from nurseries that are known to be free from the disease. And in this connection it is a pleasure to state that, so far as is now known, all the nurseries of this State are free from crown gall.

Plate II.

It will not do to try to remove the galls before the tree is planted, as it is likely that with the greatest care some of the organism will remain. In that case the disease has been introduced into the orchard, and the infection of the healthy trees is only a question of time. The majority of trees that are infected in the nursery, when planted in Colorado, make an unsatisfactory growth, and probably but few of them ever live to produce paying crops.

The disease does not appear to be so destructive to older trees, but nevertheless its effects are severe. Some experiments conducted in Arizona indicate that in such cases the disease may be held in check in a measure. The mode of treatment consists in examining the trees every season and cutting away all traces of galls from about the crowns. The wounds are then thoroughly covered with a paste made after the following formula:

Copper sulphate (bluestone), two parts.
Iron sulphate (copperas), one part.
Lime (unslaked), three parts.

The three ingredients are reduced to a fine powder then mixed thoroughly, after which enough water is added to make a thick paste.

All diseased wood should be collected and burned.

The important point, then, in controlling crown gall would seem to be to keep the disease out of the orchards, and in order to do this it is necessary to secure nursery stock that is free from the infection. All possible assistance should be given the County Inspectors in their inspection of nursery stock. In counties where many trees are being planted, sufficient assistance should be provided, so that there will be no possibility of any shipments being overlooked. And, finally, some means should be devised whereby the importance of inspection can be impressed on the growers, since, in some instances, they antagonize the inspectors and hinder their work. It is no doubt true, that the inspection of nursery stock alone, if well done, pays many times over for all the expense incurred, even in those counties which expend the most money in orchard inspection.


COLO. EXPT. STA.

Bulletins 87-90. June, 1904.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

THE PLAINS OF COLORADO

Bulletins by J. E. Payne.

87. CATTLE RAISING ON THE PLAINS.
88. DAIRYING ON THE PLAINS.
89. WHEAT RAISING ON THE PLAINS.
90. UNIRRIGATED ALFALFA ON UPLAND.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1904.

THE AGRICULTURAL EXPERIMENT STATION.

FORT COLLINS, COLORADO.

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INTRODUCTORY.

BY THE DIRECTOR.

These particular bulletins, as well as several already issued, are a contribution from the studies made by the Experiment Stations on the Great Plains of Colorado.

When the agriculture of the state is under consideration, attention is usually confined to the irrigated area of the state and the plains are not considered. It has more commonly been thought that the plains were material for future development rather than of present importance. It has, however, been felt by the more careful observers that they were agriculturally of considerable importance, and that their extent is so large that the product from any given area does not need to be large to make the aggregate worth consideration. The plains of Colorado are limited on the West by the foot-hills of the mountains and on the East they extend to the state line, hence their extent East and West is two hundred miles, and North and South the whole width of the state. There is thus an area of forty thousand square miles, forming the Plains in Colorado.

Irrigation is confined to a limited region near the mountains and tongues of land extending along the Platte and Arkansas rivers. The area under irrigation east of the mountains is less than four thousand square miles. Almost every foot of the Plains is intrinsically as productive as the areas under irrigation, provided it could be supplied with water. This condition has been so evident that there have been many dreams that the whole area of the Plains would be irrigated in the future, not realizing that such a hope is an impossibility from the failure of the water supply, hence the Plains must substantially remain as plains, and their development must recognize the limitations of climate and of water, taking advantage of every favorable feature, and based on conditions as they are.

The settlers who came with the expectation of growing the same crops and using the same methods as in a humid country, instead of adapting themselves to the conditions, were doomed to

failure and gave a bad name to the Plains. With fuller understanding, a more just appreciation of the capabilities is being obtained.

In 1893 the Legislature caused a branch Station to be started near Cheyenne Wells. The trials for the first few years were under the hope of finding the means of growing the same crops grown on an eastern farm. As the failures were many, and each from whatever cause meant the loss of a year's work, the experiments on this line were both costly and time-consuming. They resulted, however, in indicating such crops as might be partially or wholly successful. During the first few years, Mr. J. B. Robertson was superintendent, and was succeeded by Mr. J. E. Payne, a graduate of the Kansas Agricultural College. The results of the first few years are published in the Annual Report of the Experiment Station for 1900, and also as an excerpt in "Results of Six Years Trials of the Plains." When the Station was organized, it was expected that the State would make appropriations for its maintenance, but it did not and the expense fell upon the Hatch fund from the General Government. The Department of Agriculture has ruled that this National appropriation could not be used to maintain a sub-station.

When the present Director took charge of the Experiment Station it was evident that it was time to change the method of investigation. It was found that there were many settlers on the plains who were more or less successful. Mr. Payne was set free from the confining duties at the sub-station, provided with suitable field equipments to visit the settlements to learn their successes and failures, and especially to study the causes, whether due to crops, to local condition of soil or rain-fall, or to a personal element of a skilful and persistent leader. A great part of the Summers of 1901, '02 and '03 were spent in the field, mostly between the Platte and Arkansas Rivers. Some reconnaissance trips were also made South of the Arkansas and North of the Platte.

The previous work of the farm at Cheyenne Wells, though unsuccessful as a farming enterprise, was of great value in preparing for this work on the plains. It has already led to the publication of Bulletin 77 on "Unirrigated Lands in Eastern Colorado;" to Press Bulletins, 16, 17 and 18, on the "Prairie Dog as a Range Pest," "Trials of Macaroni Wheat," and "Crops for Unirrigated Lands," as well as to the present series of Bulletins. The Station has kept closely in touch with some of the Communities and the active individuals in the communities as mentioned in Bulletin 77. It has distributed Macaroni Wheat to many settlers on the plains in small quantities, and through the aid of the Department of Agriculture, to a number in quantities sufficient to plant several acres with good success.

These studies were made to get the facts necessary for an intelligent understanding. They show that the conditions of the plains are changing, and with the passing of land into private ownership, that the conditions of the open range are different from what they were a few years since. A large portion still remains public land and is likely so to do for years to come. In one respect it has been unfortunate, because it is then to no one's interest to protect the grasses but rather to get as much return as possible, without regard to the killing of the grasses and the deterioration of the range which was inevitable. The range will support fewer cattle than it used to do. A consideration of the situation inevitably brings up the consideration of the range question as an important public factor. These introductory statements can scarcely be made without a word as to the irrigation of the plains, and to answer the numerous inquiries of this kind which are received. There are no running streams on the plains. There are many dry channels which contain water after floods. Some of the streams like the Republican or Cherry Creek have water near their heads which soon dissapears. The possibilities of irrigation from streams are therefore limited. It takes the water from three to five acres of mountain water shed to irrigate one acre of land. If a corresponding ratio could be maintained on the plains through storage reservoirs and catchment of floods, 20 per cent. would be an extreme estimate.

There are almost no attempts yet made for irrigation from storm waters other than catching floods in stream channels and conducting them into reservoirs. Some small attempts have been made to catch water in plow furrows on gentle slopes. The result has been promising enough to encourage further trials. There is an increasing tendency to raise water by windmills. From all these methods small areas may be expected to be developed and give a small percentage of irrigated land, with the unirrigated lands used under range conditions.

Colorado Agricultural Experiment Station

BULLETIN 87. JUNE, 1904.

Cattle Raising on the Plains.

By J. E. PAYNE.

History in Brief. In 1867 a Massachusetts editor, when traveling from Omaha to Denver by stage, spoke of the country from Fort Kearney to Denver as 400 miles of uninhabitable space. The whole country between a short distance west of Omaha to the Rockies was considered a desert by nearly all hunters and travelers. Notwithstanding this the same men today will say that that country then supported more roving buffaloes than the number of cattle now kept on the same area. Between 1860 and 1875 the buffalo were driven out of this space and the Indians were subdued so that it was comparatively safe for men to keep cattle there. Cautiously at first, and recklessly afterwards, men went into the cattle business, until in the eighties the tally books of the various outfits whose cattle ranged eastern Colorado summed up nearly half a million head. The most of these cattle were owned by large outfits, supporting high-salaried officers and employing superintendents and foremen to do the real work. These large companies took possession of the open water along the streams and soon it became an unwritten law among them to allow each ten miles of open water and the valley adjoining it, and from the stream half way to the nearest open water on another stream or in another locality. It was the custom then to allow the cowboys to run their own cattle with those of the company and have them cared for the same as if they belonged to the company. The care consisted usually in rounding up, counting what could be found, branding the calves, and selecting animals to be sent to market.

For sometime all the range was entirely open and cattle whose owners lived on the South Platte might drift to the Big Sandy, or possibly as far as the Arkansas river. Under this system it was impossible to improve the range stock, so in the eighties the large companies began to fence large pastures and use pure bred bulls of the beef breeds. The pasture method was quite

economical as the only hands needed were enough to ride the fences to see that they were kept in repair and do a little extra work around the home ranches.

Following this era came a wave of settlement. As all the country was fenced as cow-pastures, the people had to settle in the pasture claimed by someone. During this era of claim-taking the cow-boys of the different outfits, after finding it impossible to bluff the settlers out of the country, filed in many cases on the land containing the open water of the streams, leaving the smooth upland for the settlers who came to farm.

This wave of settlement came just after the hard winter of 1885-86 had destroyed fully one-half of the cattle on the plains and had caused many owners of cattle to be discouraged and ready to quit the business. At the same time an order was issued by President Cleveland ordering all men having public lands fenced to take down their fences. This, with the crowding of settlement and the losses from the storms during 1885-86, caused the majority of the large companies to go out of business and be succeeded by men with smaller herds.

Haste of these men in getting out of the cattle business probably helped to make the period of low prices experienced in 1889-93. During these years cattle were considered very poor property, still those who stayed in the business found themselves on the top wave of prosperity a few years later when ordinary calves sold for $15 and $20 per head at five months old. But the old way of raising cattle by turning them loose and leaving them without further attention except at round-up time, had passed. The day of large herds had also passed and could not be recalled. Today a man in eastern Colorado owning as many as 1,000 head of cattle is as rare as was the man or company owning 20,000 in 1885, and between the South Platte and Arkansas rivers individual holdings of less than 500 are the rule. The majority of the cattle in that region are held in herds of less than 300. During the eight years I have been among the cattle men on the Plains the oldtimers have spoken of the winter of 1885-86 with awe, and remarked that another winter like that was likely to come at any time, "and when it does come it will clean us out," is the remark which usually followed the statement.

The winter of 1902-03 was the hardest since 1885-86. Old-timers say that the reason the losses were not greater then was that the cattle are kept closer home and owners are able to get their cattle in and feed them. Some who attempted to winter without feed lost nearly all they had. Some fed so much that the cost of the feed was more than the value of the cattle. The owners of cattle are now compelled by public sentiment to feed so as to keep their stock from starving and they did this in 1902-03.

If they had not the losses would have been seventy-five per cent of all cattle on the Plains instead of probably less than twenty per cent as it was.

The settlers came to the country to farm and settled so thickly that they left no range for stock. After the crop failures in 1893-94, settlement was thinned so much in many communities that there was room for the remaining settlers to pasture as many cattle as they wished. From that time settlers began to gather herds about them until now the country is again almost as much overstocked by the small herds as it was before by the large holdings. Two years ago it began to look as though the grass would soon be eaten out, but the losses during the winter of 1902-03 probably checked the increase sufficiently to postpone the evil day indefinitely. Practically all settlers are now cattle owners, and many of the men own just the number that can be well cared for by the owner and his family.

Water Supply. In early days the water supply was limited to that furnished by running streams, springs and storm water which collected in basins on the prairie during heavy rains. This, during dry seasons, limited the pasture used to areas within three to five miles of water holes. This caused the grass to be badly tramped and eaten out at times near the water while there was plenty of good grass on the divide. When settlers came in on the divides they dug and drilled wells so that in a few years the whole country could be used the year round, while before wells were made the divides far from the stream were used only occasionally after heavy rains. I have observed the Big Sandy valley and the adjacent grazing land from Limon to the mouth of the creek. The upland near it was never homesteaded as was the upland along the headwaters of the Republican, so it has been left practically as it was in the days of range cattle. During the time I have been acquainted with this valley, the grass and even the sage brush have been kept eaten down quite closely, especially in winter, for one to three miles back from the water. Then the grass would improve from that point until it appeared to be practically untouched over large areas. Cattle ranging in the Big Sandy valley often go out or are driven out to some water hole on the prairie where the water has gathered during a heavy rain and remain there until the water at that place is gone when they return again to the valley.

Some of the best and most humane cattle men claim that cattle should never be compelled to graze more than two miles from water. If this be true, it would double the value of the Big Sandy range if wells were put down four miles from the stream and about three miles apart on either side of the open water. The Sand Hills are counted the best grazing land, but if they are

grazed too closely they lose the sod which holds the sand in place and again become moving hills as those of Colorado were forty or more years ago. Some of the sand hill country is considered capable of carrying forty head of cattle per square mile, while the best clay land pasture will carry only about twenty-five head per square mile.

Numbers Today Compared with Number of Buffalo and Number of Cattle in the 80's. Concerning this question we find no way of getting a fair comparison concerning the number of animals living east of the Rocky Mountains at different periods. It resolves itself into a guessing contest with no one able to decide who is the winner, and one man's guess is about as good authority as another's. Assessors' returns would be official and we believe that these are more nearly correct for 1902 than for 1885 or 1879, but we find by observation that some assessors find nine-tenths of the stock in the country they canvass while others may not find more than half. Arapahoe County comprised the same territory in 1879 that it did in 1902. An estimate made by stock men and dealers in 1879 credited Arapahoe County with 60,000 cattle and 87,000 sheep, while assessors' returns for 1902 credit the same territory with 67,000 cattle and 85,000 sheep. A few years later (in 1885) there were probably more cattle and sheep in the country than in 1879. I have tried to get estimates of the number of cattle and sheep pasturing in the county in 1885. Have received estimates from several old time cattle men. These estimates give the numbers owned by different outfits. They differ so widely that I cannot credit any of them. One gives 10,000 cattle and another 20,000 cattle to the same outfit. Taking averages of the estimates it appears to me that the stock pastured in eastern Colorado in 1885 was about equal to that kept on the some territory in 1902. But much of the stock was then kept only a part of the year and then sent to market. It is my opinion, (which I cannot prove to be true, neither can anyone prove it to be untrue) that more stock is kept the year round on the Plains of eastern Coloado today than ever before in the history of the country.

As a cattle range the territory under discussion is broken up by the irrigated lands along the Platte and Arkansas rivers which now feed thousands of cattle and sheep during winters and also by small dry-farming districts near Wray, Idalia and Colorado Springs. The adobe land in the Horse Creek region and also northeast of Hugo and other places was for a long time a death-trap for cattle companies which were managed by inexperienced men who tried to use adobe land for winter range. That variety of soil is now used only as summer range, and cattle are not put on grass there until the spring storms are past. In summer the

the grass on these ranges is extremely good, but when the soil is soaked with water, cattle cannot travel far enough on it to get enough grass to sustain themselves without gathering great balls of mud on their feet which wear the animals out completely. These factors change the conditions so much that we cannot compare the eastern Colorado of today with the eastern Colorado of 1885 and treat it as a cattle range.

Today cattle are raised mainly by what might better be called "stock-farming" than cattle raising pure and simple, that is, crop production in some form usually goes with the stock raising. Comparatively few men now attempt to raise cattle entirely without feed.

Buffalo Once Ranging Over the Same Territory. The buffalo was a range animal—pure and simple. Natural laws would govern its numbers. When the buffaloes became too numerous the feed would be so scarce that the extra number would starve and this would give the range a chance to recuperate. Old-timers have often told me that there were more buffaloes in the country in the early days than there are cattle in the same region now. Travelers told of "traveling all day through a herd of buffalo." Suppose that they did "travel all day through a herd of buffalo" how many would it take to make the show spoken of? The buffalo is preeminently a gregarious animal and it might be more than one hundred miles from one herd to another. I have seen 3,000 head of cattle scattered over a range three by five miles, and at a little distance one on horse-back, or in a wagon would consider them as covering the country as far as he could see. Then 6,000 would have covered the space for the same distance on each side. This would make 6,000 cattle on the range for every five miles. 250,000 cattle spread in that way would make the same show along the Kansas Pacific Railroad from the Kansas line to Denver. Travelers could travel for days and weeks without seeing buffalo. Also the buffalo were limited in their grazing to within a reasonable distance from water. This would compel them to congregate along streams just as the cattle do along the Big Sandy now. If there were as many buffalo watering at the Big Sandy now as there are cattle watering there, it would excite the imagination of the hunter so that he would think he saw a half million where there might be 50,000.

Pastures vs. Open Range. Only a few have tried keeping their cattle in fenced pastures. Those who have kept their cattle in such a way find it more a question of water supply convenient and sufficient than of range. Without doubt if the whole range was divided into numerous small pastures with plenty of good water conveniently located in each, so that no animal had to walk more than one or two miles for water, the country could support

a much larger cattle population than it does now. The cattle could be moved from one pasture to another so that one pasture could recuperate while the cattle were grazing in the others. This plan when tested in Abilene, Texas, increased the value of the pasture quite rapidly. The important question in every case is the water supply. If only one square mile is available, then dig the well in the middle as nearly as possible and fence in four pastures and have watering troughs in each of the four pastures into which the tract is divided. Such a small holding as this would necessarily mean a dairy in connection and cows of the dual-purpose class. Those having larger areas under control could afford to raise beef cattle exclusively and all could improve their stock at their convenience without interference from the scrub stock kept by neighbors. The expense of fencing is the main argument against the keeping of cattle in pastures in communities where the land is all in the hands of private parties. But in a few years the amount which is saved in wages for hunting stray cattle and following the round-ups will pay for the fence. Also the owners always know where the cattle are and if he wants to sell one the buyer does not have to wait a week or so until the cattle can be found. Of course as long as there is Government land the pasture idea cannot be used fully, but it can be used partially. At present the men who own land often fence their own land and save the grass on it for winter range for their stock, running their stock on the open range in summer.

The use of "drift-fences" on government land is often quite beneficial to all who use the range partially enclosed by them. Often combinations of them almost enclose large tracts of pasture land. These immensely reduce the labor of controlling the cattle and keeping them on their own range. I have seen 3,000 head of mixed cattle handled by two riders by the judicious use of "drift-fences."

Range Improvement. Improvement of the range under present conditions may be classed with "iridescent dreams" of the cow man. No man is considered a good business man who will spend his money, strength and thought in improving something which is subject to being taken possession of by another as soon as it appears to be desirable property. For this reason the prairie dogs are allowed to increase while the cow-boys ruthlessly kill every hawk, badger, rattlesnake, and bullsnake that they can, thus leaving the real enemies of the range (the prairie dog) to increase without hindrance until they make their homes in the front yard of the "home ranch." Occasionally a prairie dog is killed for sport, but such cases are comparatively rare. Usually the range deteriorates so slowly that its lessened value is not noticed until some extremely dry summer or very severe winter.

The range cow-man is accustomed to seeing large numbers of cattle very poor and is not surprised when several of the poor ones die. He takes the hide and philosophically remarks that "the old cow's time has come." When cattle are high in price the range man buys cattle to the limit of his credit instead of the limit of his pasture and winter feed. The rule is, the more cattle a man has the less winter feed he gets stored for them. Then after running all summer on an overstocked range the cattle start into winter poor. In buying the cattle it is likely that the man has bought a goodly quantity of mange and contagious abortion. If to this combination is added an unusually cold winter with much snow evenly distributed so as to cover what little grass is left, then the greatest factor in "range improvement" under present conditions, thinning out by death from starvation, gets to work. After the winter is over the creditors take what is left and the range is allowed a few years of comparative rest, while the same man or others gain the "*nerve*" to restock it to its capacity. Eras of extremely low prices for feeder steers work the same beneficial results in range improvement as in the above case.

Methods of range improvement have been suggested in another paragraph. As yet we have found no grasses better than our native grasses, so it seems that the best way to improve is—rest and time for recuperation.

Winter Feeding. Twenty-five years ago a cow man in western Kansas remarked "If there was a hay stack on my range which my cattle could get to, I'd burn it and pay the owner for it rather allow my cattle to eat it." That kind of talk has been very popular among the cow men on the plains. But during the past few years the sentiment in favor of feeding during the winter has grown rapidly. Chief among the factors which have brought about this change of sentiment is the Humane Society which now has agents who travel over the plains looking for cases of cruelty to animals. Some say that most cattle men are subject to fines if the strict letter or spirit of the law was enforced. Some make no attempt whatever to provide feed for their cattle, even for times of storms. Some prepare to feed during storms and very few put up enough to feed all winter, practically none do this. Usually six weeks feeding would exhaust the feed of the man who has put up the most feed. In ordinary winters it is only necessary to feed all cattle during storms and the weak ones all the time. The feed which can be raised consists of roughness such as corn fodder, Kaffir corn, sorghum, wheat, barley and rye hay and millet. I have found sorghum and some varieties of flint corn to be the surest crops tried on the Plains. These practically never fail to produce fodder. Many find spring rye the most economical crop to raise and some stick to millet as best for

their conditions. I would not advise anyone to try to raise any of these crops by dry farming on adobe soil, but on sandy loam or the lighter clay soils these crops are fairly sure to pay in a series of years. Sorghum fodder can be produced at a cost of $2 per ton in a series of five years on sandy loam land. This will certainly be cheaper feed than shipping in feed, hay and corn.

When cattle are pastured during the summer on adobe land it is necessary to get them to some other place for wintering. Those who pasture the adobe soil near Horse Creek usually take their stock to the Arkansas Valley to feed during the winter. Hundreds of cattle are wintered now in the little nook of farming country about Wray, Vernon and Idalia. In the winter of 1902-03 many took their cattle to that country to winter and thus saved a large per cent of them from starvation. Some of the cow men have not fed a cow for so long that they have no idea how much feed an animal needs. Some men feed such a small amount that it will not sustain life, while others feed so much at the first feed that often animals are foundered and never recover. Many feed grain altogether when they feed during the winter, and allow their cattle to get their rough feed from the prairie. The way roughness is usually fed, strong cattle will not rustle for grass after having been fed a small feed of fodder, but will if fed a small feed of grain. I have seen fodder fed by scattering it over the range. Those who fed their cattle in that way claimed that the cattle would eat the fodder and then go on eating grass the same as they would if they had happened upon a few bits of grass which grew taller than the ordinary grass. This method can be used when a man can keep stray cattle away from his herd.

It has been the experience of cattle men that after they have begun feeding an animal the feeding must be continued until the grass comes. It is also better to feed the weak animals full feed instead of trying to make them rustle for a part of their living. If given a partial feed they die and all that is given them is lost, while if well fed and sheltered they get through the winter in good shape and are soon equal to the stronger cattle that rustled all winter.

Shelter. This is one of the most important factors in stock raising. Cattle kept warm and dry do not need as much feed as those exposed to the rain, snow and winds of winter. A cow covered with an overcoat of frozen snow soon loses ability to eat and her owner is lucky if he gets even her hide. If both food and shelter cannot be furnished, shelter should be chosen, because cattle in warm quarters, like a sod-sided shed covered with a water-proof roof, will go out on the range after a three days' storm and soon fill up on the dry grass, while without shelter cattle can eat very little during the storm. Fodder and hay cannot be fed

in an open lot during a wind storm, and it is very hard to feed grain even in troughs in the open during the progress of a storm. But as a rule those who have no further preparation for shelter than a corral made of barbed wire seldom have to face the problem of feeding their cattle there during a storm. Usually their cattle are scattered over the range sometimes as much as fifty miles from their home corrals. Such cattle are lucky if they range in a hilly country as they can then find some shelter in the gullies and beside bluffs along the creeks. In rough country the snow does not usually cover all the grass as there are so many varieties that grow comparatively tall in such locations, instead of being limited to a few inches in height as are the grasses which grow on the level lands.

Diseases. During the time of high prices, cattle were shipped into eastern Colorado from many places and nearly every man there bought cattle to the limit of his credit. With these cattle were imported a few undesirable diseases. Diseases like opthalmia could be seen, and the man who bought cattle affected with those could blame himself. But itch or mange was not in evidence among the cattle during the summer so as to enable a man to see it on wild cattle. Neither was contagious abortion visible when the cattle were shipped into the country. But the next winter after the cattle came in, itch developed in a large proportion of some importations, and some herds of fine looking heifers, which were sold at high prices, were found to be infected with contagious abortion to the extent of ninety per cent in some cases. The contagion spread to the sound cows which were in the herd before the purchase of the strange cattle. The remedies for these diseases were simple, but extremely expensive. The mange on the cattle had to be destroyed by dipping the cattle, and the corrals and all scratching places disinfected. If these measures were thoroughly carried out all over the country, the mange would be stamped out in a season.

There are various remedies suggested for contagious abortion, but the most effective one is to send the whole herd to the slaughter house and stock the range with calves, or with cattle from a range where the disease does not exist. Afterwards when one sees a fine-looking lot of young cows offered for sale, he had better leave them alone until he knows their history or the condition of the herd from which they came.

There is one neighborhood where I have never heard of a case of contagious abortion and practically no mange. In that neighborhood no cattle have been sold by the speculators. Those people started several yeers ago with only a cow or two apiece and have bought no cattle except bulls since.

Loco. This is one of the bug-bears which lurks about the range country. I have never found a man who has seen enough of the progress of a case of locoed animal to be able to give a complete history of a single case. The history given is, "I turned a horse out one time and did not see him for several weeks. He then acted strangely. I saw him eating the loco plants and later he would eat nothing else. He became weak and emaciated and finally died."

I have seen a great many animals that were said to be locoed I have seen a few eating loco plants. I have also been, in a few cases, unsuccessful when attempting to make a "locoed" animal eat the loco plant. At one time we heard of a man who had 200 steers, ninety-five per cent of which were said to be locoed. We spent sometime on that range and we could not find enough of either loco weeds or brown sage (which was also accused of causing the trouble) to support an animal more than a few days. The loco plants growing in the pasture where quite a number (about fifty) of the locoed steers were confined, were mostly untouched by them. We saw a few plants which had been partially grazed off. I tried to feed green loco plants to a steer which was confined in a shed. He would not eat the weed, but ate corn and alfalfa hay with a relish. The range on which these steers were kept was a very poor range. There was very little grass which they could get. Later one steer which was badly affected when I was at the range the first time, died, and the bone of one hind leg was found to be decayed so that it broke with but a slight pressure.

In every locality where loco was said to be prevalent I found the range to be very poor. This scarcity of food seems to go with loco outbreaks. I have often found a scarcity of loco plants as well as a scarcity of edible grass. At one place where I saw loco plants so thick that at a distance the patch showed but little else except those plants, the party using that range told me that his herd had never had a case of loco.

I have noticed that there is more talk of loco when there is danger of new settlers coming in on the ranges occupied by old-time cattle men than at any other time. A "terrible outbreak" of this kind occurred just as the U. P. Land agents began to bring buyers into the country four years ago (in 1900). Some of the parties who talked the most about loco have since told me that the U. P. R. R. was getting to "thinking too much of their land and putting too high a valuation on it, so the old settlers there wanted to show the Railroad company that the land was not worth so much." Others told me that an animal would not eat loco until it was almost starved to death.

Such a variety of symptoms are described by different parties who describe locoed animals that it is possible that quite a num-

ber of as yet unnamed diseases (at least unnamed by the stock men) exist on the range, and whenever an animal acts queer it is called "locoed."

The remedy usually applied is to take the animal away from the range upon which it has become diseased and feed it plenty of nutritious food.

Financial Results of Stock Raising. The main question at issue is, "Does stock-raising on the Plains pay?" The answer cannot be a definite "yes" or "no." The results of a venture depend upon the man behind the business, and also upon the conditions which he happens to meet in the work. We have known some men who made money raising cattle when prices were lowest and have met others who have broken up when prices of cattle were at the highest point. Close attention to details, an accurate acquaintance with the conditions existing upon the range used and good judgment in buying and selling are all among the factors which give success. If the herd is small the cows must be milked in order to make the profits sufficient to support a family. A man with ten cows can make a good living for his family and get ahead financially if he selects cows which give a fair amount of rich milk, and milks and cares for them properly. This man can raise feed enough to feed seven months in the year and keep his young stock growing all the time. He has but a small amount invested, and therefore his taxes are light. His stock stay near home and the expense of hunting for strays is small.

The man who has one hundred cows must hire some work done even if he raises no feed. He will be lucky if wintering does not cost him at least $3 per head in feed and losses from starvation. If he sells fifty head of cattle at $25 per head, his total income will be $1,250 per year. Out of this he must pay all store bills, feed bills, lumber bills, etc., and by the time he has paid all bills and the interest on his investment he may not be ahead of his poor neighbor who milks the cows. But one man cannot figure out the results in advance for either himself or another and get them as they will come out in actual practice. Taking it all around the personal factor is the main one in this, as in every other business venture.

Colorado Agricultural Experiment Station

BULLETIN 88. **JUNE, 1904.**

Dairying on the Plains.

By J. E. PAYNE.

History. During the days of mail coaches a milch cow was a curiosity on the Plains west of Fort Kearney. Probably the old hunters occasionally captured a buffalo cow and amused themselves trying to extract enough lacteal fluid to tone their strong coffee, but I doubt that their efforts were successful, except as an amusement. Those were the days of condensed milk, and they all found it easier to milk the can than to can buffalo milk. Later, when the Texas longhorns had taken the place of the buffalo, the cowboy who had the hardihood to try milking the dun Texas heifer probably extracted as much fun per quart of milk obtained as did the hunter who milked the buffalo "bossy." When the large companies took possession of the country, the horde of high-salaried officers who occasionally visited the "home camps" of the companies, had to have more delicate food than the jerked steer and drop biscuits which prevailed at many cow camps. So good milch cows were brought in and kept in enclosures near the permanent camp or home ranches of the outfits. These supplied plenty of milk, cream and butter and enabled the cooks to manufacture dishes fitted for the palates of the rulers of the range. Of course the old hen also lent her portion to the feasts. Ranches fitted in that way were exceptions in those days, but some of those located hundreds of miles from towns would be able to furnish many luxuries to the visitor.

When settlement first came into eastern Colorado there was a good local demand for dairy products. A few settlers brought cows with them, many had worked at dairying in their old homes and they saw the opportunities open to them in that line in the new country. When new settlers were constantly coming into the country, times were good and poor men could live by working for those who had brought money with them. But when the hard years of 1893 and 1894 came, this source of revenue for the poor man was cut off. Most of the men who had extra riches left the

country, or ceased making improvements. Then the poor man who had no cows could not stay in the country. He had to go where he could work for somebody. Those who had a few cows and a flock of chickens could stay and many of them did stay where they were by taking care of their cows and chickens. Many of these people had not enough property at that time to sell for enough money to pay their little store bills and pay their car fare to their old homes. Many old settlers have told me that they were "unable to leave the country during those hard times, so they stayed and grew comparatively rich."

In 1895 beef cattle increased in price, and the increase continued in 1896-97, until almost any calf would sell for $12 to $20 when old enough to wean. With beef cattle at these prices, it became more profitable to raise calves than to milk the cows and make butter. Also, those who had a few cows in 1893 had so many by 1898 that they could make a living from the herd without milking the cows, and often they had not much time for doing much dairy work when they had so many cattle to look after. Herds continued to increase until the range was overcrowded so much that the calf crop grew lighter, and often many of the cows would starve to death during the winter. A period of speculation came in 1901 and 1902, when many of the settlers bought cattle to the limit of their credit. This overstocked the range almost everywhere on the Plains and this overstocking caused immense financial losses. With many it again became necessary to begin milking the cows in order to get money to pay the interest on the money they owed. So we found many cows being used for dairy purposes in 1903. The low prices obtained for feeder steers compelled the people to milk their cows. During the early days attempts to support creameries were made at a few points, but these failed for lack of patronage when beef cattle took the country. A skimming station has been in operation at Burlington a few months at a time for several years. This was not in operation in 1903 as it had been superceded by hand separators.

During the past two years hand separators have grown in favor among dairymen. They find that they can raise better calves by giving them the freshly skimmed milk than they could by feeding skim milk which had been to the skimming station and back. Also, by use of the hand separator, they take only the cream to market and thus avoid handling so much weight uselessly. In 1903 there were ten hand separators in use near Wray, ten near Akron, about the same number near Burlington, and one at Cheyenne Wells. I also heard of some being in use at other points.

The cows first in use for dairying were such as were brought

to the country by the settlers or such as could be bought at the ranches. The dairy type of cows had a chance to become prominent during the hard times. In 1896 there were some Holstein and Jersey cross-bred animals in the country. But as beef cattle rose in price the dairy types of cows diminished until now they are hard to find. Cattle which are grades of one of the beef breeds are seen everywhere. In Washington county, Polled Angus and Galloway grades occupy most of the range. In Yuma county the honors are about even between Shorthorns and Herefords. The same is true of Kit Carson county. In Cheyenne and Lincoln counties Hereford grades predominate, but the other three leading beef breeds are well represented. Then there are many Mexican cattle in some of the country which is purely a range country. Practically all the cattle on the plains in other counties, as well as in the counties named, are of the same character. Nearly all of the cows have been allowed to run with their calves during the season. Very few of them have been touched by the hand of man, except at branding time.

Cows raised and trained in the manner described and which are cross-breeds of beef-making breeds instead of dairy breeds, are not likely to prove to be very profitable dairy stock. After the settler has decided to return to dairying, it will require two or three years to train cows for the business so as to make it profitable from the business-man's standpoint. The range cows give milk during only about five months of the year. They must be trained to give milk during ten months. The cow that has become accustomed to running with her calf will not readily consent to adopt a man to take the place of the calf. If forced to submit to being milked by a man, she cannot be compelled to give all her milk. In order to get a herd ready for dairying, the heifers must be broken to milk and developed as milch cows. By choosing the best from large numbers, a herd may be obtained which will give some profitable returns the second year. If the heifers pay expenses the first year, they will do well. Some men milk a large number of cows after the calves are weaned, getting a little from each cow for a short time. This is pure gain to the man who does his own work as nothing is fed the cows and they are milked in order to keep the udders from spoiling.

Some milk their cows during the summer, or during the time when grass is good, and allow them to go dry when the cold weather begins and it is harder for the cow to get plenty of feed on the prairie. With the average range-bred cow, this is probably the best way, because she will not respond to heavy feeding by giving more milk. Instead they will put on flesh when fed heavily. When they have dairy cows they can then find profit in feeding costly feeds during the winter. As it is now it will re-

quire from one to five acres cultivated in sorghum to feed a milch cow through the season of poor grazing. A man who has ten cows can milk them and raise enough feed to feed them and their calves through the winter. The feeds that he would be likely to raise are wheat and millet hay, corn fodder and sorghum. Some years he would raise enough grain to make a good ration for the cows, and during some years he would have only roughness which he could profitably use with some of the concentrated feeds which are on the market. At present practically all the settlers use the forage and grain which they can produce and buy as little as possible. Ensilage should in the future be a part of the winter rations of the milch cow. I have frequently been asked about ensilage by settlers who were thinking of doing winter dairying. No trouble should be experienced in making good ensilage anywhere on the Plains. In fact the Australian stockman makes ensilage by stacking the green forage above ground just as it is cut, and weighting the stacks heavily. I would not advise this, however, because forage is too scarce on the Plains to afford to waste the amount that is lost by making ensilage in the stack. In many locations it is easy to make a pit near the bank of a creek or ravine so that a door may open from it into the ravine. This will resemble the costly silos which are built above ground. On level ground an immense cistern will answer the purpose perfectly. These underground silos will be used at less expense than the silos built above ground, as the green fodder does not have to be elevated. It can be merely thrown into a pit and trampled down solid. Of course the pit will be better and more substantial if the walls and bottom are cemented. In filling the silos the green forage should be run through a cutting machine and the stalks should be reduced to pieces one half inch to one inch in length. An ensilage cutter suitable for filling small silos which can be run either by a windmill or by horse power can be bought for about $40 or $50. By making the green feed into ensilage the waste caused by the hay and fodder being covered with dust by the wind storms, may be avoided. The pit silo can be made by the home labor with no cash outlay. After it is filled it should be covered to a depth of one and one half to two feet with hay or straw, or any trash which will keep the dirt out of the cut feed, and then earth should be thrown upon that covering to weight it down. About one foot of earth should be enough, but the weight of earth should be put on according to the depth of the ensilage in the silo. I have seen one foot of earth put upon eighteen feet of ensilage with good results.

Shelter. In nearly every locality good sod is available for building purposes. The adobe soil furnishes the best sod for this purpose, but any stiff clay soil will make a strong wall. Light

sandy loam soils do not make good soils for building. The wall may be built two feet thick of sod, then a good roof of either lumber or shingles should cover the building which is to be the winter shelter of the dairy cow. Some make the covering of rough boards and lay sod on top of the boards. Some thatch the building with sorghum or other rough hay. All the coverings except those of wood must be frequently renewed or they leak so badly that the building ceases to be a shelter.

Results. Comparatively small returns from dairying on the Plains are the rule. One creamery man remarked to me that "a settler could milk a three-year-old steer out of a cow every year." That may be true but in order to do that the cow must be fed, and it will be a good steady job for one man to milk twenty cows and raise feed for them. If then, three-year-old steers are worth $35 each, a man by hard and confining work, may get $700 for his years work. This is a theoretical illustration. Usually one man and his whole family manage the twenty cows or less. Some parties near Akron report a return of five dollars per cow during five months in 1903 from grade Shorthorns. This is a report from only one season's work, presumably with a selected herd of cows.

One of the oldest dairymen in Burlington, a man who never quit the business since he came to the country fifteen years ago, milks twenty grade shorthorn cows and heifers every summer, He tries to raise good calves as he counts the calves as his profit. His estimate is that the average range cow running on buffalo grass and getting no other feed will give about two dollars worth of cream per month during six months of each year. By milking enough cows the settler can make his living from the cream sold, and the calves will be the gain.

At Wray the estimates were similar. That is the cream will make expenses leaving the calves clear gain, and the weight of evidence all around pointed the same way. Of course, the better beef animal the calf is, the greater the gain, and the nearer the cow approached the dairy type the more cream she would have to yield in order to make up to her owner the difference between her bony calf and the fine calf of the grade shorthorn.

We may safely count dairying, in a modest way, a success from the standpoint of the settler in eastern Colorado. This is especially true when it is practiced in connection with the production of medium to good feeding steers. Of course choice steers cannot be produced in connection with dairying on the range without using so much feed that the cost is likely to be too great for the returns obtained. If the dual purpose cow has a place anywhere it is on the Plains of eastern Colorado, where men

must milk the steer's mother in order to be able to keep the steer until old enough for the feed lot.

Dairying is a confining business, but it is a business which will give employment at modest wages to all who are able to get a few cows and settle on a piece of government land. With dairying the plains country will support five times the population it will support under the system of raising beef alone. All who can get a location within fifteen miles of a railroad station can sell cream. Those farther from shipping stations would better work at cheese making which has proved very profitable in many localities.

The greatest source of profit in dairying in eastern Colorado is not in the production of dollars or steers, but in the training of the boys and girls to habits of thrift and industry. Where no cows are milked about the only thing left for the children to do in the purely stock-raising sections is to ride around the country on ponies and drive cattle. If any feed is raised they may work in the crop-raising a part of the season, but the chances are that they will grow up comparatively idle and not learn to do any work systematically. But with cows to milk and care for regularly and the calves to feed, there will be something for every child to do who is strong enough, and each member of the family may be helping to earn something to provide luxuries as well as necessities. Also, the income from the sale of cream will come monthly, while if the sale of steers is depended upon the income, as a rule, comes yearly.

Colorado Agricultural Experiment Station
BULLETIN 89. **JUNE, 1904.**

Wheat Raising on the Plains.

BY J. E. PAYNE.

Eastern Colorado was settled mainly by people from Kansas and Nebraska. These people had raised wheat as a main crop in their former homes and as a matter of course began planting wheat when they came to the new country. The usual successes and failures followed. In 1892 an immense crop was raised, but 1893, 1894 and 1895 were hard years for the wheat growers. The years following were not so bad as 1893 and 1894. Wheat planting began in earnest in 1888. The average of wheat per acre reported by a number of representative farmers now living near Vernon and Idalia for the eleven years, 1888 to 1899, inclusive, is ten bushels per acre. This includes the years when the crop was an entire failure, on account of drouth, hail or insect enemies.

In common with other new countries, this country seemed poorly adapted to the growth of fall wheat when it was first settled. Many tried fall wheat, and sowed it until they lost their seed and then quit. In 1900 there were only a few small fields of fall wheat in the country, but a series of comparatively damp autumns have encouraged the settlers to again sow fall wheat, until in 1903 fields of fall wheat were seen to be quite common. Those who grow fall wheat claim to get one to two bushels more per acre from it than they get from spring wheat, and the buyers pay five cents per bushel more for it than for spring wheat, so there is considerable inducement offered for trying to raise it. On the Idalia divide, about one half the wheat seen by me in 1903 was fall wheat, while on the Vernon divide about ten per cent of the wheat was fall wheat.

During the years 1902 and 1903, a spring variety of macaroni wheat has been introduced into the country. It is a hard wheat and seems to be quite drought-resisting, although it has as yet, given only about the same yield as the ordinary spring wheat. About 2500 bushels of this wheat were grown on the two divides in 1903. For a time the growers seemed unable to find a market for their macaroni wheat after they had raised it, but when deal-

ers in Kansas City learned that they could buy it by the car-load, the growers found no trouble in selling all they did not need for home use. Local millers and dealers thought that they could not handle the wheat. Millers needed special machinery for getting all the flour out of it and local grain dealers were afraid to handle it lest it should become mixed with the other wheat and render it unsalable. Recently a miller at Fort Collins has been trying to get macaroni wheat for sowing above the ditches where irrigation is impossible. He promises to buy all that can be raised at the same price that ordinary wheat commands.

Varieties of wheat used in the most of the wheat-growing districts are not usually known. Certain types of seed wheat happened to survive the drought years, either successfully resisting the drought or by having been kept in granaries through these years, have since been sown continuously. These are now known as "white wheat" or "red wheat" sometimes with the name of some settler prefixed to the type-name. I failed to trace the origin of any of the seed used, but believe that quite a number of varieties are grown there, usually very much mixed now. When the macaroni wheats were introduced, it was feared that they too would become mixed with the other varieties and reduce the value of the common wheat. In time the growers of macaroni wheat may fear that the soft varieties may become mixed with macaroni wheat and reduce its market value.

Preparation and Seeding. Probably almost every method of preparation of the seed-bed and planting has been tried by someone at some time since settlement began. In some years success "chased" the farmer who used the most slovenly methods, while in other years she outran and kept out of reach of the man who used the best methods known in the art of farming. This happened so often that some settlers have contracted the habit of putting the seed into the ground by use of the least possible amount of work, and they say they are sure of a good crop if the rainfall comes right, and are sure of a failure if the rainfall does not come right, no matter how the grain is planted.

Following out this idea, some have continued to sow the seed broadcast, either with a broadcast sowing machine which is attached to a wagon bed, or by hand. The seed is sown on the ground which has received no preparation to fit it for a seed-bed. Weeds may cover the ground, or it may be bare. The seed is then covered with either a corn cultivator or a disc harrow. Sometimes the ground is not harrowed after the seed has been covered, and sometimes it is harrowed with a smoothing harrow.

Some good farmers tried plowing the ground thoroughly before sowing the wheat. But after a time so many failures were received by using this method that the best farmers ceas-

ed to plow their ground for wheat. As a rule the ground which is plowed for wheat is not worked enough to make a good seed bed for the plants. So the soil dries out and injures the crop when droughty periods come. With ordinary tools it is next to impossible to make a seed-bed sufficiently compact for the wheat plant after the soil has been plowed shortly before sowing. Too much air space is left in the soil and this is fatal to the feeding roots of the wheat plant. With special tools for packing the soil after plowing an ideal seed-bed may be made. But this requires so much work that one man could not seed a large area to wheat as is the custom now. It is possible for one man to plant 300 or 400 acres to wheat, but if he plowed the land and then prepared it properly after plowing, he would be able to plant only 80 or 100 acres. In seeding on plowed land, the hoedrill has been used. The press drill is superior to the hoe drill as a machine for planting where drought is so often a prominent factor in determining the results. The disc press drill is also considered an especially good tool for use in the dry farming country.

For a long time some farmers claimed that broadcasting the seed and then covering with a disc harrow or a cultivator so as to thoroughly stir all the top soil and put the grain into the ground in contact with firm soil was the proper method to sow wheat. Then the disc seeder was invented. It did, at once going over the land, exactly what they held was best. With plenty of teams, a man could put in a large acreage single-handed, then if the crop was a failure, he would lose nothing except the seed and his own labor, while if the crop was good, he could well afford to hire plenty of help to harvest and thresh the crop. But as land becomes more valuable, I notice that more work is put on the preparation of the soil, and seed drills grow in favor.

When I first visited the wheat growing district of eastern Colorado, many of the best farmers told me that they had grown wheat on the same ground year after year, sometimes as much as ten crops in succession, and the soil did not show any signs of being worth any less for wheat growing than it was the first year wheat was sown upon the land. Two years later all admitted that the land was surely failing when wheat followed wheat. In 1902, I noted fields which demonstrated the difference between wheat after wheat and wheat after corn. In some cases wheat following wheat gave a yield only five bushels per acre, while wheat following corn in the same field, produced fifteen bushels per acre. It is now generally admitted that it does not pay to sow wheat after wheat. The rotation usually practiced is corn one year and wheat the next.

Fall plowing for spring wheat has not been a success. The best explanation for this is that during the winter the soil dries

as deep as it is plowed and this through drying seems to lock up the plant food temporarily so that the wheat plants do not grow well. Sorghum before wheat is bad for the yield of wheat, in fact it seems that any crop which is not cultivated thoroughly during the growing season is a poor one to precede a wheat crop. It is probably true that if the corn is not thoroughly cultivated the yield of the wheat crop following it will be materially reduced. One man has for a few years practiced listing his ground in the fall for the wheat crop of the next spring. He reports an increased yield of from one to two bushels per acre by using this method, as compared with the ordinary method of preparing the ground. One year a heavy rain came after a part of the ground was listed. The next year that part of the listed ground which was packed down by the rain gave no better yield of wheat than the ground prepared in the ordinary way.

Crops Raised Outside the Main Districts. Wherever one goes he hears of the enormous crops of wheat raised in 1892. At Akron the visitor found wheat piled up everywhere during the fall of 1892. They could hardly get cars enough to carry it out of the country. Yields of 30 to 40 bushels to the acre were common. At Thurman about the same yields were obtained. Settlers at Cheyenne Wells and Burlington also obtained heavy yields of grain that year. But outside the Vernon and Idalia divides, very little grain has been produced since. This may not be because it could not have been produced, but because the droughty years following caused nearly all the settlers who did not favor making a stock country of the region to become discouraged and leave the country, leaving its population sufficiently thinned to permit those remaining to have all the free range they could use. Under these conditions stock-raising was so profitable that the settlers could not afford to raise wheat.

Soils and Other Influences. The soils of the Plains are quite well adapted to the growth of wheat. This has been proved whenever the rainfall has been properly distributed during the growing season. The soils near Vernon, Idalia and in the eastern one-third of Kit Carson county, are very much alike, and under similar conditions, would produce about the same yields of wheat. But the Vernon divide is protected from the ravages of hot winds by the groups of sand hills which lie on the northern and western sides of it, each of these groups being about twenty miles across. The influence of the sand hills dwindles rapidly as the location is farther to the south and east. The Idalia country is not quite so free from hot winds as is the Vernon country. By the time Burlington is reached the influence of the sandhills is practically nothing, while at Cheyenne Wells, one could not possibly know that the hot winds were tempered by any influence. These sand

hills absorb all the water which falls upon them. They also receive in addition the drainage from about as large an area as they cover which lies west of them. They seem to cover the lower courses of the streams which start on the clay lands west of the sandhills. This moisture influences the humidity of the area which the hills partially surround, and while the rainfall is practically the same at Wray as at Cheyenne Wells, the air is more humid and so does not absorb the water from the soil and from vegetation so rapidly as does the air in less protected localities.

The rule seems to hold good that the greater the percent of clay a soil contains the more water it must have in order to produce a crop. It is a noticable fact that during dry years the men living on black sandy land produce better crops of all kinds than those living on clay lands, but where the rainfall is abundant the clay lands will give larger yields, especially of wheat, than the sandy lands.

One encouraging fact which should be here noted is that the samples of macaroni wheat grown in eastern Colorado have been pronounced to be the best seen which has been grown in the United States. The rainfall is never enough to damage the quality of macaroni wheat. From present indications it is possible that in a few years very little wheat except macaroni wheat will be grown in eastern Colorado, and it is also likely that the wheat-growing districts will be greatly enlarged by the use of this variety.

Use of Straw. For a long time the wheat-raisers had little use for their straw. Sometimes the straw would accumulate for several years if it was not burned, but during the past four years they have been wintering cattle in the wheat growing districts because the range has become so crowded that there was no winter range in many localities. This influx of cattle from the pastures surrounding the farming districts has furnished a profitable market for all the straw which is produced. At the same time the feed raised in the farming country has saved the lives of thousands of cattle.

Results. The real results of a business are not correctly estimated if only the volume of the business is known. While the yield of wheat per acre will not average more than eight bushels on the two divides during the fifteen years it has been grown there, that does not tell of the profits and losses sustained by the settlers. Of course the settlers have been forced to raise corn in order to raise wheat. Then they raised hogs because they raised corn. They gathered cattle because they had so much rough feed as a by-product from the wheat and corn raising. This has changed the period during which the farmer had employment for himself and family from 90 days during the year

which was necessary in wheat raising alone, to 365 days which is necessary under the mixed farming of the present day. Some men have lost all the property they brought to the country, but others who came with practically nothing are quite well-to-do now. The banker at Wray, who is an old settler himself and is personally acquainted with almost every man on the Vernon divide, especially from a financial standpoint, told me that a large majority of the settlers there are better off, financially, than they were when they came there. The good dwellings and barns seen there seem to prove the statement.

Magnitude of the Wheat-growing Industry on the Plains. At Cheyenne Wells, no means of threshing grain is available except a little tread-power machine. At Burlington, very little threshing is done because no threshing machine is near enough to afford to come there for the work it can get. The wheat there is used for feed, usually for hay. At Yale, several stone rollers are in use at times when a crop of grain is raised. At Seibert, there is a small horse-power thresher which usually operates near Tuttle, Kirk and Cope. At Thurman is another small horse-power which threshes a few jobs each season. At Akron I saw no threshing machine. The flail is the only weapon in use there at present. But on the Vernon and Idalia divides, nine threshing outfits are in operation nearly every year. Some of these are large steam-threshers which carry hands enough to do all the work so as to deliver the grain to the owner's wagons. Often the machines are all busy from the middle of August until far into December. Of course the machinery in use for threshing indicates the relative production of grain. There are three grain buyers at Wray, and besides what these men buy, much goes to Haigler, Nebraska, St. Francis, Kansas, and Burlington, Colorado. There is a good flouring mill at Wray and another at Burlington.

Next to stock raising under the range system, wheat growing requires fewer days work in the year than any other farming business, so wherever wheat can be successfully grown, farming may gain a foothold. Where it fails habitually, the stock must occupy the country.

Colorado Agricultural Experiment Station

BULLETIN 90. JUNE, 1904.

Unirrigated Alfalfa on Upland.

BY J. E. PAYNE.

Since the wave of settlement flowed into eastern Colorado in 1886, men in isolated localities have been testing alfalfa as a forage plant for the unirrigated lands.

During my travls I have had several small plats of alfalfa under observation, usually seeing the crop one or more times during each year. Near Vernon, Robert Brady had a field which he used for a hog pasture for several years. The plants kept dying out until there were practically none left. Another patch near Vernon survived as much as five years or more. It was cut for hay a few times. One year it was nearly three feet high when cut. When seen in 1903 it still showed a thin stand. Another patch on the same farm was sown in the spring of 1900. In 1901 it gave a heavy crop of hay, but has not grown tall enough to cut since. Jas. Slick had a small field of alfalfa which he used as a hog pasture for several years. The grasshoppers destroyed what was left of it in 1902. In 1902 he sowed five acres, but the grasshoppers have kept this down so that so far it has yielded very little forage. Russian thistles also came in and occupied the field as soon as the alfalfa plants were killed out.

Near Logan, Geo. Bond had about four acres in alfalfa which he used for hog pasture for several years. He thought that it payed well. A. C. Brown, who lives on the Kansas line about seven miles northeast of Lansing, had three acres in alfalfa when I saw the place in 1900. This patch had been seeded about seven years then. Mr. Brown told me that he cut it twice some years, once some years and during some other years it did not grow high enough to cut for hay. The average yearly yield of hay Mr. Brown estimated at one ton per acre.

Near Idalia, John Gillespie sowed eight acres to alfalfa in 1902. Both 1902 and 1903 were so droughty in his neighborhood that he has not yet cut a hay crop from it. The same experience was met by John Reidesel and Chas. Ingalls, and also by some others who sowed about the same time. Near Vona, S. L.

Howell sowed five acres to alfalfa in 1902 with the same results as were obtained in Idalia.

In 1897 one half an acre of alfalfa was sown at the Plains substation at Cheyenne Wells and a good stand was obtained. The weeds were kept mown down that year. In 1898 one half a ron was cut from the plat at one cutting. The grasshoppers took the other cuttings. In 1899 the plat was mown once for hay, yielding about one-fourth of a ton. The grasshoppers killed many plants and the Russian thistles took the place of alfalfa. In 1899, 1900 and 1901 there were fewer alfalfa plants left each year and no hay crop was cut either of those years. By 1901 there were so few alfalfa plants left that the land was planted to another crop.

Again in 1899 four acres were seeded to alfalfa May 20th. A good stand was obtained, but during the hot summer weather that on the higher land died. About one acre on low land which was occasionally overflowed by water drained from the prairie across it continued to grow well. In 1900 this part yielded one cutting at the rate of one ton per acre. Grasshoppers gradually killed this patch out until in the spring of 1903 so little was left that it was plowed up and the ground planted to other crops.

Planting. The important factor in getting a stand of alfalfa is getting a good seed bed for it. My experience has taught me to plow the ground early in the season five to eight inches deep, harrow until it is thorougely packed and then wait until the ground is thoroughly wet before planting the seed. If this occurs before the middle of July go on the ground with a light drag harrow as soon after the rain as the surface appears to be dry and break the crust thoroughly. Then sow the seed broadcast and follow with the harrow. A good stand has been obtained every time I have followed this rule, but if a drill is available the same rule should be followed except that the seed should be drilled in as soon as the ground shows dry on top. Some have been successful with the hoe drill and some have used the press drill. One man seeded his alfalfa with a lister, taking off the shares and running the seed in behind the subsoiler part of the machine. The time to sow alfalfa may be any time when the ground is in good condition between the 10th of May and the 15th of July.

Having a stand of alfalfa the next question is how shall it be maintained against its enemies, the drought and the grasshoppers? It has been demonstrated in western Kansas that thoroughly discing the alfalfa field usually increases the yield of hay, while it also prevents the deposit of grasshopper eggs in the field.

Enemies. Drought is one of the worst enemies of alfalfa without irrigation, but this may be overcome to a considerable extent by cultivation after the plants are well established, and

thorough preparation of the ground before planting. After leaving the drought out of consideration, the next enemy of importance is the grasshopper. These, working in conjunction with the drought, make the planting of alfalfa a very discouraging proposition. Grasshoppers are fond of almost all kinds of green food, and alfalfa being green in summer when the native grasses are dry, the grass hoppers come to the alfalfa patches in countless millions when other food becomes dry. When the soil is left undisturbed, they breed in the fields and in such cases keep the plants eaten down throughout the season. Thoroughly stirring the soil with a disc harrow prevents the grasshoppers breeding in the field and it has to contend with only the hoppers which grow on the prairie. By using hopper dozers the number of grasshoppers may be kept down without damaging the crop. These machines can be used only in fields where the plants are but a few inches high. Poisoning by using arsenic in bran or other substance which is relished by the hoppers is often successfully used. But the most profitable method I have ever seen employed is the poultry remedy. Some people keep so many chickens and turkeys that the grasshoppers are held in check by them. In August 1901, I visited the orchard of A. E. Tabor who lives ten miles southeast of Wray, and found many trees entirely stripped of bark and leaves by the grasshoppers. I visited the same place in 1903 and found the trees and garden in a good condition. He told me that the presence of about 400 chickens and turkeys were responsible for the good condition of the trees, and also for the scarcity of grasshoppers which I noted.

Mr. B. D. Prentice and Mr. Rufus Roberts, both living near Laird P. O., both gave testimony which coincided with what I observed at the home of Mr. Tabor. Dozens of other cases of the same kind could be cited showing the same results. The main difficulty in working the poultry remedy, is that the coyotes must be kept away or they destroy the poultry.

Location. There are many locations which catch water in considerable quantities from surrounding land. These, if occupied by moderately light clay or sandy loam soils, are ideal places for sowing alfalfa to be grown without irrigation. I have seen places where from 40 to 80 acres could be found in such alocation.

Conclusion. Alfalfa growing without irrigation deserves a trial upon a larger scale than I have yet seen, and when grasshoppers are held in check sufficiently it will certainly pay. As it is, it is the only perennial forage plant which I have seen that I would plow up buffalo grass to test upon a large scale. And when large fields of it are planted, the grasshoppers will not cut such a figure as they do now when the grasshoppers from several square miles concentrate upon a few acres.

Bulletin 91. June, 1904.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

POTATO FAILURES.

A SECOND REPORT.

—BY—

F. M. ROLFS.

PUBLISHED BY THE EXPERIMENT STATION,
Fort Collins, Colorado.
1904.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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Bulletin 91
Colorado Experiment Station

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(4) Large segmented hyphae from a spore culture of **Corticium vagum, B and C,** var. **solani** Burt. Spores caught in potato agar and transferred to potato plugs on the fourth day. Drawings made on the twelfth day. No difference can be observed in these (Nos. 3 and 4) hyphae.

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Potato Failures

SECOND REPORT.

By F. M. ROLFS, M. S.

PART I.

INTRODUCTION.

Line of Work.—Bulletin 70 of this Station gives the results of our experiments and study of *Rhizoctonia* of the potato for the year 1901. Work on this disease has been continued during the past two years. The practical value of corrosive sublimate and formalin solutions have been tested, over 120,000 pounds of seed tubers have been treated and the the influence of the treatment on the plants and crops carefully noticed. Seed selection has received considerable attention, and the influence of irrigation and cultivation on the development of the disease has also been studied. A fruiting stage of the fungus has been studied both in the laboratory and in the field.

Historical.—This disease is common to the fields of Europe, and has been reported from many localities in the United States. It is difficult to find a lot of tubers which are not more or less infected with it. Its origin is not known, however, its rhizoctonia and sclerotia stages were first reported by Kuhn, and European literature contains a number of publications on this malady. Its history in America is comparatively recent, dating back to only 1900. To my knowledge only four* publications on this potato disease have appeared in this country. Curiously enough the fruiting stage of this fungus has been overlooked, or at least never associated with the rhizoctonia and sclerotia stages, and some of our ablest workers have supposed it to be a sterile fungus; careful study, however, shows that it produces spores abundantly.

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*1 { Bulletin 186 N. Y. Cornell Exp. Station.
   { " 186 N. Y. Agr. " "
2 " 70 Colo. Agr. " "
3 and 4 Bulletins 139 and 145 Ohio Agr. Exp. Station.

DEVELOPMENT OF FUNGUS.

The fungus is truly a parasitic organism, flourishing in heavy, wet soils; and our observations during the past three years show that it produces fruit only on or near the living tissues of plants. Its development may be divided into the following stages:

The Rhizoctonia Stage.—Two forms of hyphal growth are constantly associated with the injuries resulting from this fungus —a light and a dark colored. The light form usually develops deeper in the tissues and is more actively parasitic and frequently produces a wet rot of the stem and old seed tubers, while the colored, or rhizoctonia proper develops more freely on or near the surface of the roots and tubers. The colored form is also frequently found growing in the soil some distance from the plants and is constantly associated with the fruiting stage of this fungus. (See Plate V., 1.)

The Sclerotia Stage.—The hyphæ give rise to dark irregular-shaped bodies which are made up of a mass of large, close-septate hyphæ. (See Plate V., 2.) These bodies are known as sclerotia. Experiments show that this stage is well adapted for tiding the fungus over unfavorable periods, and that it is a prominent factor in the dissemination of this disease. The sclerotia resemble closely particles of soil and are frequently mistaken for scales of dirt adhering to the tubers. When infected tubers are used for seed these Sclerotia produce hyphae which in turn injure and often kill the plants.

The Corticium Stage.—The young plants developed from seed tubers, which are more or less covered with the sclerotia stage, usually have their subterranean parts covered with a network of dark hyphæ. This dark network advances with the growth of the plant until it reaches the surface of the ground, where it changes into a grayish white fruiting layer, frequently entirely surrounding the base of the green stem and often extending up the stem for a distance of four inches. (See Plate I., 3.) The tips of the outermost hyphæ of this fruiting layer develop into basidae, which usually bear from two to four stregmata (See Plate III.), but in a few instances six have been observed. The spores are hyaline and usually ovate in form with apiculate bases; fifty spores taken just as they occurred on a green stem gave an average measurement of ten by six u. But mature spores after they had fallen measured twelve by eight u, the largest measuring fifteen by thirteen u, and the smallest nine by six u.

The hyphal characters, form of basidae, and structure of fruc-

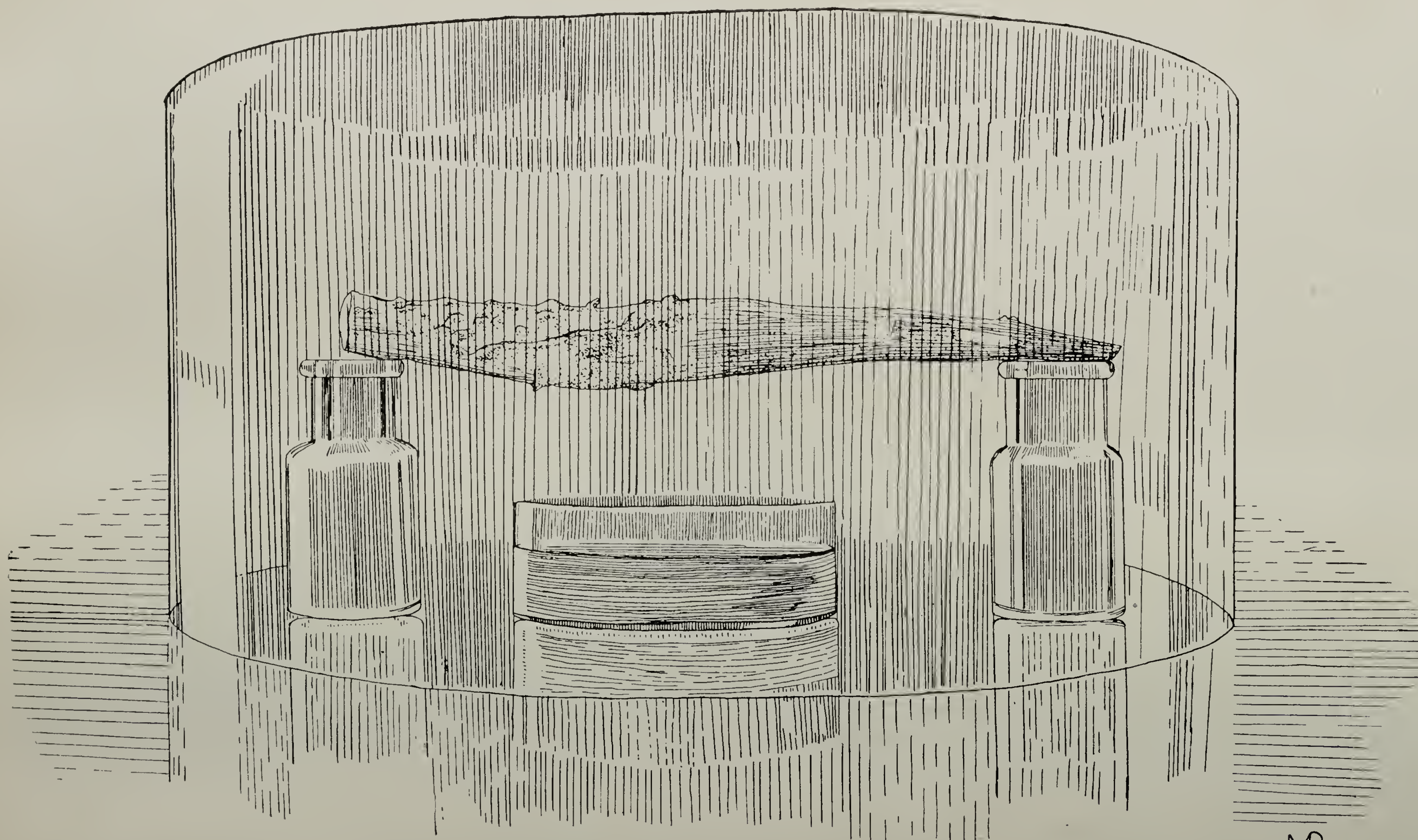

PLATE II. Arrangement for catching spores.

tification, show that it belongs to the well known species, **Corticium vagum* B. & C., but its parasitic mode of life, size and shape of spores, have been considered of sufficient distinction for a new variety and it is designated as *Corticium vagum* B. & C. var. *solani* Burt. This stage has been observed only on or near green potato plants. The fruiting layer does not adhere firmly to the stem and cracks and falls off very easily when the stem becomes too dry, consequently all traces of it usually disappear soon after the death of the plants.

From 225 pieces of stems covered with the fruiting layer placed in agar, 203 developed pure cultures of the *Rhizoctonia*; 15 *Fusarium* and 7 *Altenaria*. Cultures from this fruiting layer have been carefully watched during the past two years and they resemble in every way the pure cultures developed from the Sclerotia and pure cultures developed from hyphæ taken from a rotten tuber. All attempts in the laboratory to induce this fungus to develop spores on various culture media, have failed. However, if diseased tubers are planted in a suitable place they will produce plants on which the fruiting layer grows and develops spores abundantly.

The spores fall as soon as they are mature, consequently it is difficult to obtain cultures by the usual methods. The following plan was finally devised, which has proven quite satisfactory: A stem on which the fruiting layer had developed was suspended over a petri dish containing agar. The stem and dish were then covered with a sterile bell jar. (See Plate II.)

Spores show considerable difference in their germinating power, frequently they germinate within a few hours after they fall on agar. Each spore usually pushes out one germ tube; occasionally, however, two tubes are formed. The tube as it emerges from the spore is constricted and reaches its normal size at from 10 to 15 mm. from the spore. The growth is comparatively slow during the first two days and septa are only occasionally observed. About the third day side branches develop and the septa become more noticeable. By the fifth or sixth day the hypæ have taken on many of the *Rhizoctonia* characteristics and branch freely. Sclerotia usually form on potato plugs in twelve days.

Over sixty pure cultures of *Rhizoctonia* have been obtained from the spores of the corticium stage and these cultures resemble those obtained from the sclerotia on tubers and those made from seed tubers rotted by the hyphæ of *Rhizoctonia*.

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* This fungus agrees well with the description of *Hyponochus solani*, Prill. & Dell., but several specimens of it were sent to Dr. E. A. Burt, and after carefully examining them he has concluded that it is a variety of *Corticium vagum* B. & C., for which he has suggested *Corticium vagum* B. & C. var. *solani*.

INJURIES.

Plant Injuries.—Young plants suffer severely from its invasions and are often completely cut off by it before they reach the surface of the ground. Its attacks on the subterranean stems may bring about an abnormal development of tubers, which is usually spoken of as "Little Potatoes," or the injuries may be of such nature as to interfere with the storage of assimilated food in the subterranean branches of the plant, thus bringing about an abnormal top development, and frequently green tubers form in the axil of the leaves. (See Bulletin 70, p. 5–7).

In an experiment with badly infested seed 32 per cent. of the plants were killed before they reached the surface of the ground; 17 per cent. of the plants that reached the surface failed to produce tubers, and only 50 per cent. of the seed planted produced plants that developed tubers large enough for No. 1's and many of these were scabby. On July 14, 55 per cent. of the living plants showed the corticium stage of this fungus. Seed selected from this lot, but free from the sclerotia stage, produced plants of which only 20 per cent. showed traces of the corticium stage. Plants in an adjoining experiment which were free from the rhizoctonia and sclerotia stages were also free from the corticium stage.

Scabbing of Tubers.—European investigation long ago attributed the pitting or scabbing of tubers to the attacks of *Rhizoctonia.* Our experiments and observations also show that its attacks on growing tubers frequently produce deep ulcers. Most of our scab is due to the attacks of this fungus. (See Bulletin 70, p. 11).

Rotting of Seed Tubers.—Observations show that seed tubers are frequently invaded by the light colored hyphæ of this fungus, which gradually turn the flesh watery and soft. If the tubers are rotted early in the season, the plants are not only cut off from their food supply before they become well established, but they also suffer more or less from the attacks of the fungus. Such plants usually do poorly and frequently die before the close of the season. Numerous attempts to produce wet rot by inoculating healthy tubers with both the sclerotia and rhizoctonia stages have failed; however, a dry rot has occasionally developed.

Five out of eight seed tubers infected with this fungus placed in sterilized sand on July 2, 1903, and examined three months later, were completely rotted by a wet rot produced by this fungus. The remaining three were also completely rotted at the end of the fourth month, while five check tubers which were free from the fungus remained sound.

Five cultures taken from the different parts of each of these

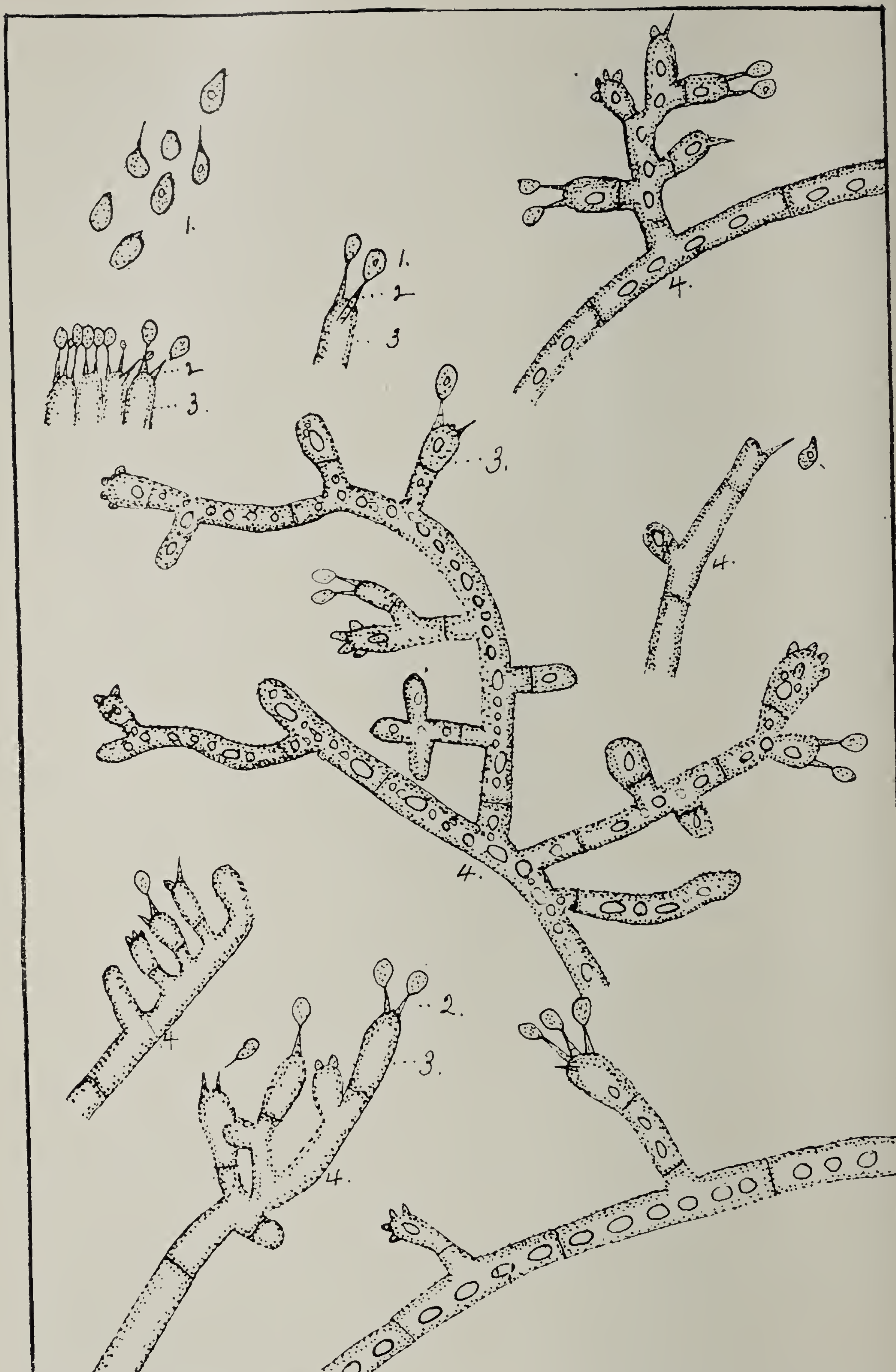

PLATE III. Hyphae, Basidia, Sterigmata and Spores of Corticium.

eight rotten tubers, making 40 cultures in all, produced pure cultures of *Rhizoctonia* in every instance.

SPREAD OF THE DISEASE.

Conditions have a marked influence on the development of this fungus. The soil and seed may be thoroughly infected and still the plants escape serious injury; on the other hand, mere traces of the disease under favorable conditions may develop and cause serious loss.

Rate of Growth at Different Temperatures.—Experiments show that pure cultures of this fungus on potato plugs and agar make very little or no growth in seven days, when kept at a temperature of about 40° F.; a slight growth at 55° F.; and a profuse growth at 72° F.

The Soil.—Some fields seem to be more favorable to the development of this fungus than others. A heavy, poorly drained soil seems to be most favorable for its development. Potatoes grown on heavy soils with good bottom drainage usually suffer less severely from this disease than those grown on poorly drained land.

It is not known how long this fungus will remain in the field when it once becomes thoroughly established, but observations of investigators show that it may live indefinitely on dead organic matter in the soil and on the roots and stems of various plants.

Influences of Heat and Moisture.—It has frequently been noticed that the corticium stage of the fungus develops freely on the surface of the ground under the potato plants and on the stems of the green plants when the ground is kept too wet during a spell of hot weather. This stage is of a light gray color and might easily be mistaken for alkali. However, some growers are quite familiar with it and know too well that its appearance on the ground under the plants indicates an over supply of water and a lack of air circulation at the base of the plants, and are well aware that if conditions are not improved the plants will be severely injured.

Laboratory work shows that a high temperature and plenty of moisture are necessary for the rapid development of this fungus. This possibly explains why extremely hot weather occasionally severely injures the plants in fields which have been thoroughly watered, while those in fields which have been sparingly watered and well cultivated remained apparently uninjured. In our experiments, when diseased plants were kept comparatively dry and well cultivated they did fairly well, but when such plants were over watered and the ground became too wet and soggy, the subterranean

parts of the plants were severely injured, and many of the tops showed marked sun scald injuries, which were followed by an invasion of *Altenaria* and many of the plants died before the close of the season.

The Seed Potato.—The sclerotia on the seed tubers is one of the principal means of disseminating this malady. It is almost impossible to find a lot of tubers entirely free from them, and some of our leading seed men send out seed tubers which are thoroughly infected. We have observed as high as 75 per cent. of infected tubers in lots offered for seed.

In storing seed careful attention ought to be given to temperature and moisture of the cellar. A comparatively dry cellar at a temperature of about 40° F. prevents the growth of this fungus, but infected tubers stored in a cellar which is warm and sufficiently damp give rise to a profuse development of both hyphae and sclerotia. A few diseased tubers in a lot of clean ones may greatly injure the seed value of the entire lot. (See Bulletin 70, p. 10).

Insect Injuries.—Frequently the larvae of insects make tunnels of considerable depths into both the stems and young tubers. The hyphae of this fungus frequently enter such wounds and may extend the injury.

Infected Plants.—This disease may be carried on the roots and stems of the various cultivated plants and weeds which grow on infected soil. (See Bulletin 70, p. 4). Infected stems and roots often find their way into barn yard manure and compost heaps; thus the manure may become the source of general infection to clean fields. Infected potato stems are frequently left scattered in the field after harvest; these are blown about by the wind and many of them finally find their way to other fields and thus become the means of general infection to new fields.

REMEDIAL MEASURES.

The Soil.—When a field has once become thoroughly infected with this fungus, it is cheaper to put it in other crops for at least three years. Evidence indicates that root crops should be avoided; cereals which are probably not attacked by the fungus should be sown on infected ground and all weeds should be kept down. Comparatively dry and loose soils, especially if they have a gravelly sub-soil, are less favorable for the development of the fungus than heavy soils. Losses from this disease are often lessened by giving careful attention to the physical condition of the soil.

Cultivation.—Too much care cannot be given to the preparation of the soil. Plowing under a green crop on infected ground from seven to eight inches deep just before planting gives good

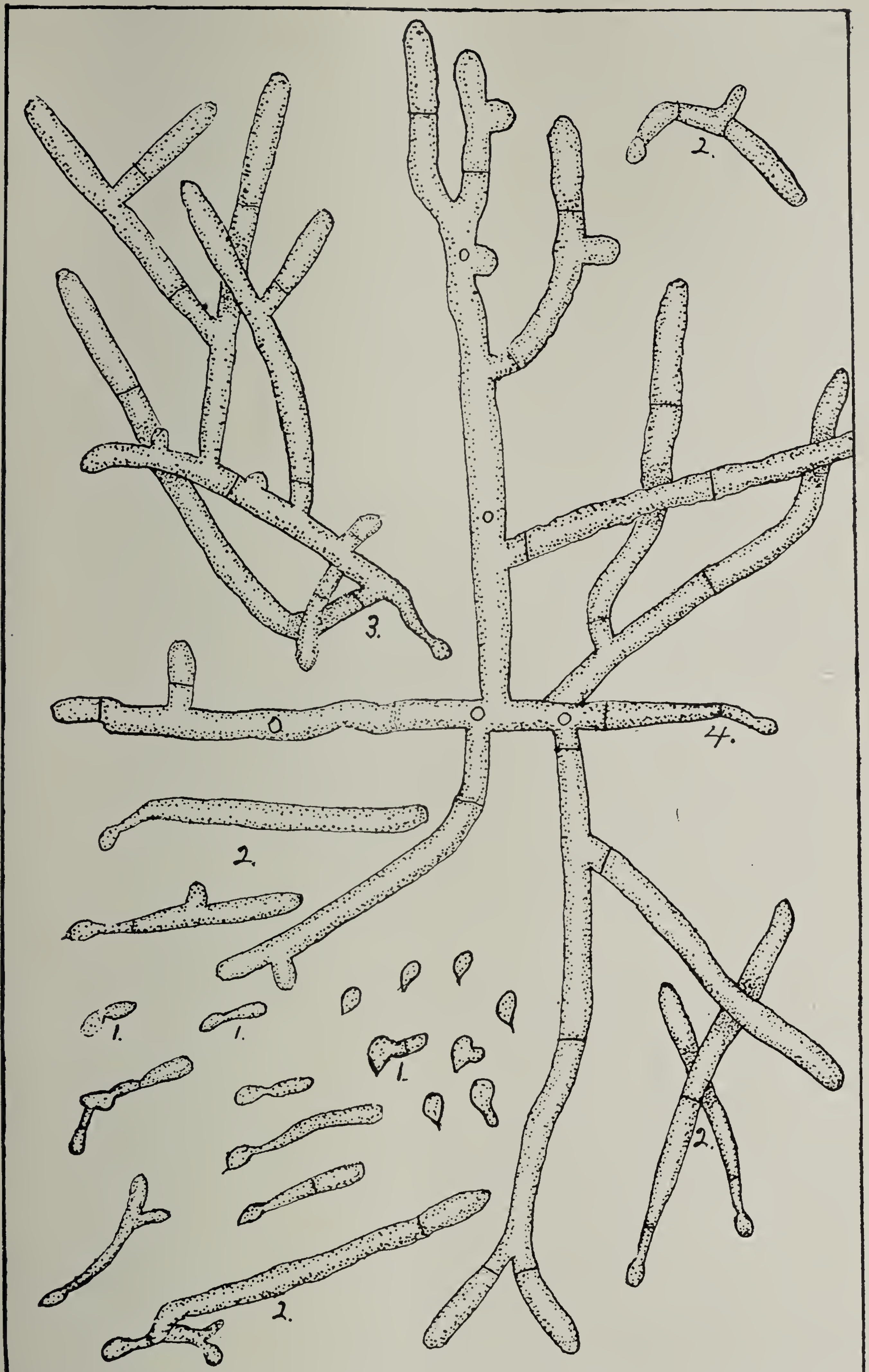

PLATE IV. (1)—Spores Germinating. (2)—Growth of Hyphae in two days
(3)—Growth in three days. (4)—Growth in five days.

results. The ground ought to be thoroughly pulverized before planting. After the seed is planted great care should be exercised to prevent the soil from forming a crust. The potato plant does best in a well aerated soil. The crust not only tends to weaken the plant by cutting off its air supply, but it also frequently delays the shoots in reaching the surface of the ground; and if such plants are infected with this disease they suffer severely and are frequently killed before they reach the surface of the ground. (See Bulletin 70, p. 6). Even after the plants are up and well-established the formation of crust on the soil ought to be carefully guarded against, since it seems to furnish better conditions for the development of this disease. Observations indicate that fields which are sparingly watered and thoroughly cultivated suffer less from this fungus and the tubers are much freer from scabs.

The Runs.—Deep runs are better than shallow ones, since they give better circulation of air at the base of the plants, and they also enable the grower to supply the roots with an abundance of moisture, while the soil near the surface, where the tubers form, can be kept comparatively dry and thus avoid conditions which favor the rapid development of this fungus.

Late Planting.—Late planting frequently gives better results than early planting. This may possibly be due to the wet weather early in the spring which makes the conditions favorable for the growth of the fungus. Later the weather becomes settled and the ground can be kept well cultivated and the moisture of the soil is more easily controlled. A loose, open soil favors the growth of the potato plant and seems to check the rapid development of this disease.

Old Stems.—Infected potato and weed stems are often left scattered about in the field after harvest, and these are blown about by the wind and many of them are lodged in irrigating ditches, where they usually remain until the following summer, and as soon as the fields are irrigated, many of the stems are carried by the water into new fields and thus may become the principal means of infection. The burning of all vines and weeds after harvest is an excellent practice.

The Seed Potato.—A careful study of seed potatoes shows that it is almost impossible to find a lot of seed of which at least a few are not more or less infected with this disease. Observations indicate that seed tubers are usually the principal means of spreading this disease. (See Bulletin 70, p. 9). Too much care cannot be given to seed selection.

Tubers keep best in a dry, well ventilated dugout which is kept at about 40° F. Seed tubers ought to be stored in compara-

tively small lots and kept at as even a temperature as possible. Spreading the tubers on the cellar floor where they are exposed to the light and air five or six weeks before planting is a good practice. This treatment usually produces strong, hard sprouts after planting, which develop rapidly and are better able to resist the attacks of fungi.

Developing a Disease Resistant Variety.—Different varieties vary greatly in their suceptibility to disease when grown under the same conditions. Even plants of the same variety often show considerable difference in their power to overcome disease. It is possible that by crossing plants which show marked disease-resisting power, a desirable variety might be originated, and later be gradually improved by constantly selecting seed tubers from the plants which show the greatest disease-resisting power.

Seed Selection.—Prof. *Bolley's work on potatoes indicates that small tubers from a vine which produced mostly large tubers of desirable form and size, have greater seed value than large, poorly shaped tubers from a strain of potatoes which habitually produced small tubers. His experiments also indicate that when pieces of equal weight from small and large tubers of the same vine were planted, there was not sufficient difference in the yield to be noticeable under farm conditions, providing all tubers were normally mature. Our experiments and observations agree quite closely with those made by Prof. Bolley, but it has been observed that elongated and ill shaped tubers are usually developed on diseased vines.

Carefully selecting smooth, round tubers and rejecting all those showing any signs of infection, gave excellent results. In selecting tubers for seed, the disease-resisting power of the plant should also receive careful consideration. Diseased plants are not only apt to produce abnormally developed tubers, but the tubers ars also usually infected. Such seed often produces weak plants, which frequently suffer severely from the attacks of fungi. *Success or failure depends much on the quality oj seed tubers used.*

No commercial grower can afford to use seed without knowing something of its past history. Those who "import seed" will find it cheaper in the end to pay more for seed and buy only from men who are known to give careful attention to the quality of their seed.

Some of our most successful growers have obtained good results from carefully selecting home grown seed just before or at digging time. This practice requires some ability and involves a little extra expense. As stated before, the size of the seed tuber

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* N. D. Agr. Exp., Bulletin 30.

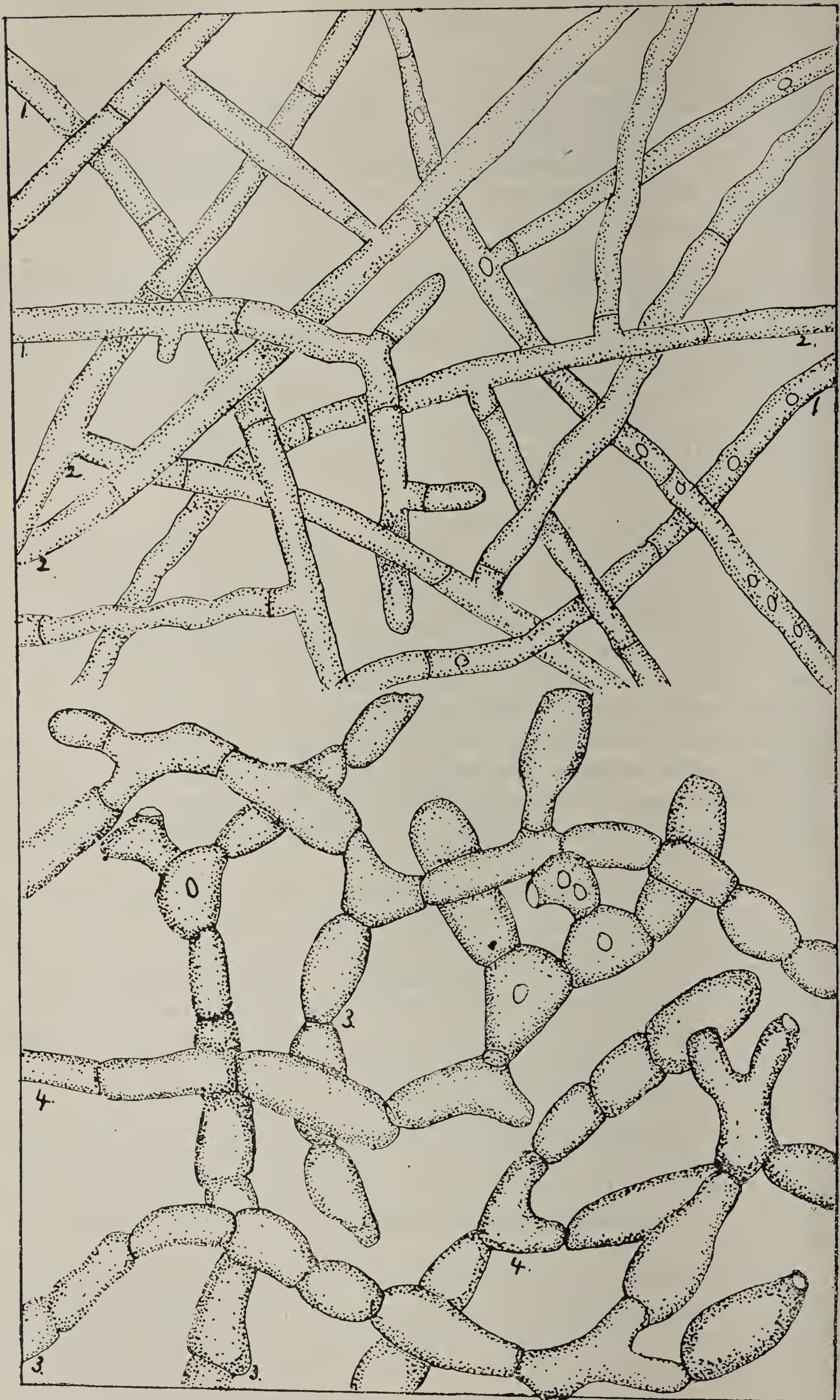

PLATE V (1)—Long Segmented Hyphae from Rhizoctonia stage. (2)—Large, Short Segmented Hyphae from a Sclerotia.

does not necessarily indicate its seed value, and unless the selecting is done in the field, the test will usually be in favor of the larger seed, since No. 2's are most likely to have a poor form and come from vines which produced mostly small tubers.

Another method which gives evidence of considerable practical value is to set aside each year five or ten acres of land for the growing of seed potatoes. The soil of such tract ought to be fertile and free from the various diseases which attack the potato plant. The tubers used in planting the seed tract are carefully selected each year from the seed plat of the previous year. The surplus seed is used for planting the general crop and in this way a strain of pedigree potatoes is gradually developed.

Corrosive Sublimate and Formalin Treatments.—The practical value of these solutions has been carefully tested. Our experiments indicate that these treatments may prevent the scabbing of tubers and improve the appearance of the crop, but usually they cut down the total yield per acre when the treated seed is planted on infected ground. However, the corrosive sublimate treatment gave marked gains when the treated seed was planted on new ground and the per centage of infected tubers in the crop was much lower. Formalin gave less favorable results, is more expensive, and weakens when exposed to the air; consequently it is difficult to keep the solution at standard strength when the dipping is done on a large scale.

Sulphur.—Thoroughly covering infected seed with sulphur at planting time apparently had very little influence on the growth of this fungus. The plants were more or less injured by the fungus, and the crop of tubers was thoroughly infected with it.

Lime.—Using lime at the rate of 3,000 pounds to the acre did not apparently check the development of this fungus. The plants did poorly, and the crop of tubers was also thoroughly infected with the fungus.

CONCLUSION.

The corticium or fruiting stage of this fungus develops freely on the green stems of the infected plants. However, it is evident that the sclerotia which are so common on the stems and tubers are also prominent factors in disseminating this disease.

Experiments indicate that treating infected seed with the standard formalin solution usually improves the appearance of the crop, but apparently weakens the plants and is apt to be the means of cutting down the total yield of tubers per acre.

The corrosive sublimate solution improved the appearance of the crop and gave marked gains when the treated seed was planted on new land. A weak solution, one ounce to ten gallons of water, gave better results than the standard when the seed was dipped in sacks and planted on old potato land.

Liming the soil at the rate of 3,000 pounds to an acre apparently did not check the disease.

Thoroughly covering the seed with sulphur also gave negative results.

The burning of all vines and weed stems as soon as the crop is harvested is an excellent practice.

Carefully selecting clean, smooth, round seed from a lot of tubers comparatively free from disease gave excellent results.

The shape and appearance of tubers give a hint as to their seed value, but their crop record and care of tubers after they are harvested are also important factors to be considered in selecting seed. Cull seed is a poor investment for a commercial grower at any price.

Spreading the seed tubers on a root house floor, where they were dry and more or less exposed to the air and light for five or six weeks before planting gave good results.

Seed tubers keep best when stored in small lots in comparatively dry, well aerated cellars which are kept at a temperature of about 40° F.

Good seed is one of the essential factors in successful potato culture; still various soil conditions seem to be fully as important. This is especially true where the soil is infected with this fungus. Observations indicate that diseased plants growing in soils well supplied with plant food are usually more successful in resisting the attacks of the fungus than those growing in soils more or less deficient in their chemical composition.

Poorly aerated soils are also more favorable for the development of this fungus. Soils which have a tendency to bake or form crusts need frequent cultivation. This is especially true while the plants are young. Plants which are thoroughly cultivated and carefully irrigated are apparently better able to overcome the attacks of this fungus and the tubers are usually free from scab.

Too much attention cannot be given to watering. If the rows are too long the field ought to be divided into sections, so as to be able to apply the water more evenly, and thus prevent part of the field from becoming too wet and soggy. Apply less water and irrigate more frequently. If the ground bakes or forms a crust, cultivate the field as soon as it becomes sufficiently dry. Keep the soil well aerated if possible.

Deep runs are also usually more desirable than shallow ones, since by this means the roots can be supplied with plenty of moisture and at the same time prevent the soil where the tubers are forming from becoming too wet, and they also furnish a better circulation of air at the base of the plants, thus making the conditions less favorable for the development of this fungus.

PART II.

DETAIL OF EXPERIMENTS.

Experiment I.—During the winter of 1900, Mr. J. G. Coy of Fort Collins, called our attention to the peculiar shape of the potato tubers grown on his place during the previous summer, apparently a mixture of Rose Seedling and Queen of the Valley. Many of the tubers were long and pointed, a good lot of what growers call "run out seed."

In the spring of 1901, seed was carefully selected from the No. 2's of the above lot, all diseased and "run out" tubers were rejected, and the seed was treated with corrosive sublimate.

The plants came up nicely but most of them blighted badly and were killed two weeks before frost. The field yielded 150 sacks of tubers per acre, and the tubers were much better than those harvested in 1900. Nine hundred and eighty pounds of the No. 2's of this crop were used as seed in the experiments of 1902. All tubers were carefully sorted and washed. The diseased and badly "run out" tubers were placed in the poor lot and are known as cull seed. There were 254 pounds of poor and 796 pounds of good seed. All the culls and 434 pounds of the better seed were treated with a solution of 8 oz. of formalin to 15 gallons of water.

The field selected for these experiments is located on the river bottom just east of town, the soil is of a black sandy loam. The field was plowed in early spring, and the seed was planted on April 25th. The rows were placed 36 inches apart and the pieces were placed at intervals of about 15 inches in the row and 4 inches deep.

The plants came up uniformly, and those of Plats IV and VI were sprayed five times. The ground was kept in almost perfect condition and the plants looked unusually promising until about July 27th, when the field was thoroughly water. From this time on the soil was compact and soggy, making the condition favorable for the development of Corticium. The roots of many of the plants were killed. The leaves and stems soon showed marked signs of sun scald. These injuries were soon followed by an attack of Altenaria, which resulted in the complete destruction of all the unsprayed plants by August 18th. The sprayed plants fared a little better, but they, too, were severely injured and were all dead and dry by August 25th. There were very few, if any, pointed tubers found in selected seed lots. In this experiment a sack of potatoes is estimated at 100 pounds.

Plat I Check—The seed of this lot was sorted with the greatest care. All diseased and injured tubers were rejected. Those which were long and pointed, or showed signs of "running out" were also rejected. The ground was quite dry at planting time, yet the plants were not long delayed in reaching the surface of the ground. This lot gave a yield of 212 sacks per acre. No "run out" tubers were observed in this plat at harvest time.

Plat II—The seed in this experiment was selected with the same care as that of the preceding plat. But it was treated in a solution of formalin on April 18th and planted on April 23rd. These plants reached the surface of the ground on time. This plat occupied the lowest part of the field; consequently the subterranean parts of these plants suffered more from the invasion of Corticium than those of the preceding plat. These plants were also the first to blight. This plat gave a return of 185 sacks per acre, making a yield of 26 pounds of tubers for every pound of seed planted,—a loss of 12%. No "run out" tubers were found in this plat at digging time.

Plat III—The culls taken from the two preceding lots were used in this plat. It was treated in a solution of formalin on April 18th and planted on April 23rd. The plat was also located on low ground, and these plants were the first to blight. An average yield of 130 sacks per acre was obtained from this plat—18 pounds of tubers for every pound of seed tubers planted—a loss of 39%. Many long and pointed tubers were taken from this plat.

Check Plat IV—The seed of this lot was sorted with the greatest of care. All diseased and injured tubers were rejected. The plants were sprayed five times with Bordeaux mixture. This experiment gave a return of 254 sacks per acre,—a return of 36 pounds of tubers for every pound of seed planted, making a gain of 40 sacks per acre from spraying. No "run out" tubers found in this lot at harvest time.

Plat V—This seed was also carefully selected and treated in a formalin solution on April 18th and planted on April 23rd. The plants reached the surface of the ground about the same time as check plants, and they were sprayed five times with Bordeaux mixture. This plat was located on the highest part of the field, consequently some of the plants suffered more or less for moisture. This plat gave a return of 193 sacks per acre,—a return of 27 pounds of tubers for every pound of seed tubers planted, making a loss of 24%. No "run out" tubers were taken from this crop. Spraying increased this yield 8 sacks per acre.

Plat VI—This seed was the last of the culls taken from the preceding lots. It was treated in a formalin solution on April 18th and planted on April 23rd. The plants came up irregularly, and many of them blighted early in spite of the fact that they were carefully sprayed five times. This plat gave a yield of 161 sacks per acre,—a return of 23 pounds of tubers for every pound of seed planted, a loss of 36%. Many "run out" tubers were taken from this crop. Spraying increased their yield 31 sacks per acre.

Results.—1. In the three experiments where the plants were sprayed five times with Bordeaux mixture, gains of 20%, 5% and 25% respectively were obtained.

2. Dipping clean, slected seed in formalin gave a loss of 12% in the first experiment and 23% in the second.

3. Cull treated seed compared with good treated seed gave a loss of 55 sacks per acre in the first experiment and 32 sacks in the second.

TABLE I., SHOWING RESULTS OF EXPERIMENT NO. I.

Plat No.	TREATMENT.	Number pounds of Seed Tubers Planted	Number pounds of Tubers Harvested	Pounds Harvested from every pound of Tubers Planted	Loss from Dipping	Number of Sacks per Acre
I.	Check	152	4605	30.29		212
II.	Dipped in Formalin Solution	217	5725	26.38	12%	185
III.	Cull Seed Dipped in Formalin Solution	64	1185	18.5	39%	130
IV.	Check, Plants Sprayed 5 Times	140	5070	36.22		254
V.	Seed Dipped in Formalin Solution, plants sprayed 5 times	217	5985	27.58	24%	193
VI.	Cull Seed Dipped in Formalin Solution, plants sprayed 5 times	190	4380	23.05	36%	161

Experiment II—The experiments given in this table were made by C. H. Bliss on old potato ground in 1902. It represents the results of experiments carefully conducted on an extensive scale, to test the practical value of these seed treatments. Great care was exercised to have the soil, watering and cultivation as nearly the same as possible. A short rotation of wheat, alfalfa and potatoes has been practiced on this place. The standard formalin treatment was used in the first three of these experiments. A weak solution of corrosive sublimate in the fourth, and a strong solution of corrosive sublimate in the last. All the treated seed was dipped in sacks.

Experiments I and III gave a loss of 11 and 10% respectively, while Experiment II gave a gain of only 3%. The weak solution of corrosive sub-

limate gave no result in one case, while in the other it gave a gain of 16%. A strong solution, on the other hand, gave a loss of 21%.

Results.—1. These experiments indicate that formalin has no marked value when the treated seed is planted on old potato ground.

2. A weak solution of corrosive sublimate has a slight value, but a strong solution is injurious when the treated seed is planted on old potato land.

TABLE II., SHOWING RESULTS OF EXPERIMENT NO. II.

Plat Number	VARIETY	TREATMENT	Number of Rows	Total Number of Sacks	Number of Sacks to the Row	Per cent of gain or loss.
I.	Pearl	Check	5	45	9	
		Formalin	6	48	8	11% loss
II.	Pearl	Check	3	24½	8	
		Formalin	4	33	8¼	8% gain
III.	Pearl	Check	4	40	10	
		Formalin	4	36½	9	10% loss
IV.	Rural New Yorkers	Check	6	40	6⅔	
		Corrosive Sublimate, weak solution	8	62	7¾	16% gain
		Corrosive Sublimate, weak solution	4	26½	6⅔	Neither gain or loss
V.	Rural New Yorkers	Check	4	27	6¾	
		Corrosive Sublimate, strong solution	4	21½	5¼	22% loss

Experiment III—These experiments were conducted by C. H. Bliss in 1902; they were also made to test the practical value of treating seed when such seed is planted on old potato ground. Home grown Rural New Yorker seed was used in this experiment. A short rotation of potatoes, wheat and alfalfa has been practiced on this place. A fair crop of alfalfa was plowed under in the spring before planting. The ground was plowed about nine inches deep and the seed was planted four inches deep on May 22. The cultivations and irrigations were the same in all the plats. The runs were made about eight inches deep.

This was an exceptionally poor season for this section, and the returns given in this table are considerably below an average crop. A sack of tubers is estimated at 100 pounds.

Plat 1 Check—The seed in this plat was rough and more or less covered with sclerotia of Corticium. This plat occupied slightly the best soil. The plants all suffered some from the attack of this fungus. Six hundred pounds of seed gave a return of 8,270 pounds of tubers. The tubers were rough and of a poor quality.

Plat II—The seed of this plat was the same as that used in check. It was treated in a solution of one ounce of corrosive sublimate to 8 gallons of water, 1½ hours on May 15th and planted on May 22nd. The plants were backward from the start and never fully overtook the check plants. All plants were more or less diseased, and the quality of the tubers was no better than those of the check plat. Six hundred pounds of seed gave a return of 6,545 pounds of tubers, making a yield of about 11 pounds of tubers for every pound of seed planted—a loss of 20%.

Plat III—All the seed in this plat was free from sclerotia; however, most of the tubers were more or less covered with hyphae. The plants

reached the surface of the ground about the same time as those of the check plat. They all suffered some from this disease, and the crop was of a poor quality and many of the tubers were covered with sclerotia. Six hundred pounds of seed gave a return of 7,555 pounds of tubers for every pound of seed planted, a loss of about 8%.

Results.—1. Diseased seed treated with the standard corrosive sublimate solution and planted on old potato ground gave a loss of 20%.

2. Seed free from the sclerotia stage, but more or less covered with the rhizoctonia stage, planted on old ground, gave a loss of 8%.

TABLE III., SHOWING RESULTS OF EXPERIMENT NO. III.

Plat Number	TREATMENT	Number Pounds of Seed Planted	Pounds of Potatoes Harvested	Yield in Pounds for every Pound of Seed Planted	Per Cent. of Loss	Number of Rows to the Acre
	Check	600	8270	13.75		5
	Treated	600	6545	10.9	20%	5
	Selected Seed	600	7555	12.59	8%	5

Experiment IV—The following experiments were made by S. A. Bradfield in 1902 to test the value of treating diseased seed with corrosive sublimate when such seed is planted on old potato ground. A short rotation of wheat, alfalfa and potatoes has been practiced on this place for a number of years. A fair crop of alfalfa was plowed under in the spring before planting. The soil in this field is of a black loam, slightly sandy; it slopes gradually to the south and east. The runs between the rows were from seven to eight inches deep, which made it possible by carefully watering to supply the roots with plenty of moisture, and at the same time to prevent the soil in which the tubers developed from becoming too wet and soggy. Second year's Divide Pearl seed was used in these experiments.

Plat I Check—This plat was located on lower and in slightly better soil than the other two experiments. All the tubers were more or less covered with sclerotia of Corticium. The seed was planted about May 18th. Five hundred and six pounds of seed yielded 11,553 pounds of tubers, giving a return of 23 pounds of tubers for every pound of seed planted. These tubers were smaller, and were more or less covered with sclerotia. Careful observation also showed that this lot also contained the most scabby tubers.

Plat II—The seed of this plat was more or less covered with sclerotia, but they were treated with a solution of one ounce of corrosive sublimate to eight gallons of water for 1½ hours nine days before they were planted. These plants were five days late in reaching the surface of the ground. A careful examination of plants from various parts of this plat showed plainly that most of the plants had their subterranean parts covered with the hyphae of this fungus. Six hundred pounds of seed gave a return of 11,161 pounds of tubers, making 18½ pounds of potatoes for every pound of seed planted, but the tubers were cleaner, larger and better in every way than those in the Check plat.

Plat III—This seed was taken from the same lot of tubers as those in the other experiments. All tubers having sclerotia on them were rejected, but many of the tubers were scabby and all of them were more or less covered with the hyphae. This experiment occupied the highest and probably the poorest ground. Five hundred and four pounds of seed gave a return of 10,574 pounds, making 21 pounds of tubers for every pound of seed planted. A loss of 9%. However, the tubers were larger and cleaner than those of the Check plat.

Results.—1. Diseased seed treated with corrosive sublimate gave a loss of 20%.

2. Seed free from the sclerotia stage, but more or less covered with the rhizoctonia stage gave a loss of 9%. The tubers were larger and of a better quality.

TABLE IV., SHOWING RESULT OF EXPERIMENT NO. IV.

Plat Number	TREATMENT.	Number Pounds of Seed Tubers Planted	Total Number of Pounds of Tubers Harvested	Yield in Pounds for every Pound of Seed Tubers Planted	Loss	Yield in Sacks per Acre
I	Check	506	11553	23		137
II.	Seed Treated with 1 oz. Corrosive Sublimate to 8 gallons of water	600	11161	18½	20%	111
III.	Washed and all tubers containing sclerotia rejected	504	10574	21	9%	126

Experiment V—The experiments in the following table were conducted by E. R. Bliss in 1902. They were made on old potato ground, but the field had been in alfalfa during the previous two years, and a fair crop of alfalfa was plowed under in the spring before planting. The seed was treated with formalin on May 20 and planted about May 24. The rows compared were of the same length, and the cultivation and irrigation in all the experiments were the same. A sack of tubers in these experiments is estimated at 100 pounds.

Lot 1, Plat I Check—Sixty pounds to the row of Prolific seed from the Divide were used in this plat. The soil in this plat was slightly better than that of the treated seed plat; otherwise the conditions were the same; only a few deceased plants were observed in this plat. This plat gave a return of 26 pounds of tubers for every pound of seed planted, a yield of 158 sacks per acre.

Plat II—Sixty pounds to the row of Prolific Divide seed were use in this plat. It was dipped in sacks in a solution of eight ounces of formalin to fifteen gallons of water for two hours. No diseased plants were observed in this plat and the crop of tubers was clean and smooth. Twenty-four pounds of seed were harvested for every pound of seed planted, making a return of 144 sacks per acre—a loss of 10%.

Lot II. Plat I Check—Fifty pounds to the row of Pearl first year's Wisconsin seed were used in this plat. It was planted May 30th. The soil, cultivations and irrigations were as nearly the same in these plats as it was possible to have them. Thirty-three pounds of tubers were harvested for every pound of seed planted—a return of 199 sacks per acre.

Plat II—Fifty pounds to the row of first year's Wisconsin Pearl were planted in this plat, which had been treated in sacks with a solution of eight ounces of formalin to sixteen gallons of water for two hours. One thousand two hundred pounds of this seed were planted on May 24th, and the remaining 2,640 pounds on May 26th. No diseased plants were observed in this plat and the tubers were clean, smooth and free from disease. One pound of seed gave a return of 30 pounds of tubers—a yield of 179 sacks per acre, making a loss of 10%.

Lot III. Plat I Check—Forty pounds to the row of second year Wisconsin Pearl seed were used in this plat. There were some deceased plants observed in this plat, but on the whole the plants were strong and vigorous. One pound of seed gave a return of 25 pounds of tubers—a yield of about 150 sacks per acre.

Plat II—Forty pounds to the row of second year Wisconsin Pearl seed were used in this lot. It was treated in sacks with a solution of eight ounces

of formalin to sixteen gallons of water for two hours. Each pound of seed gave a return of 21 pounds of tubers, making a yield of about 128 sacks of tubers per acre—a loss of 14⅛%.

Results.—1. Divide Prolifiic seed treated with standard formalin solution gave a loss of 10%.

2. First year's Wisconsin Pearl seed treated in standard formalin solution gave a loss of 10%.

3. Second year's Wisconsin Pearl seed treated in a standard formalin solution gave a loss of 14%.

TABLE V., SHOWING RESULTS OF EXPERIMENT NO. V.

Variety, Where Raised	TREATMENT	Number Pounds of Seed Tubers to row	Number Pounds of Tubers Harvested from a Row	Number of Rows in Acre	Yield in Pounds for every Pound of Seed Planted	Gain or Loss	Number of Sacks per Acre
Prolific, Divide Seed	Check	60	1580	10	26.33		158
	Formalin Treatment	60	1440	10	24.00	10% Loss	144
Pearl, Wisconsin Seed First Year	Check	50	1660	12	33.20		199
	Formalin Treatment	50	1490	12	29.80	10% Loss	179
Pearl, Wisconsin Seed Second Year	Check	40	990	15	24.75		149
	Formalin Treatment	40	850	15	21.25	14⅛% Loss	128

Experiment VI—The experiments given in the following table were made by the Agricultural Department in 1901. Rose Seedling seed was used which had been stored in a damp cellar. Many of the tubers were more or less covered with Corticium hyphae. This seed was removed from the cellar about June 1st, and placed in a dry room until June 12th, which thoroughly dried all the tubers. The field on which this seed was planted has been under cultivation for a number of years. It was plowed late in the spring and the seed was planted on June 12th. None of the plats were watered, still nearly all of the plants remained green until killed by frost.

Plat I Check—These plants were more or less diseased, but most of them looked strong and healthy until killed by frost. The fruiting stage of this fungus was observed on many of the plants. One hundred and forty pounds of seed gave a return of 767 pounds of tubers, a yield of 5 33-100 pounds of tubers for every pound of seed planted, or about 32 sacks per acre.

Plat II—This seed was of the same grade as the check lot. It was treated with corrosive sublimate one week before it was planted. These plants were a little slow in reaching the surface of the ground, but they soon looked fully as strong and vigorous as the checks. Very few scabby or diseased tubers were found in this lot. One hundred and one pounds of seed produced 539 pounds of tubers, a return of 5 17-50 pounds of tubers for every pound of seed planted, making about 32 sacks per acre, no gain over check.

Plat III—This seed was also of the same grade as the check lot, but it was treated with formalin a week before it was planted. The plants came up fully as well as those of the check plat and apparently were as strong and vigorous. One hundred and five pounds of seed gave a return of 466 pounds of smooth clean tubers, a yield of 4 11-25 pounds of tubers for every pound of seed planted, making a loss of 17%. About 27 sacks of tubers to the acre.

Plat IV—This seed was carefully selected, rejecting all tubers containing sclerotia, but all of the seed tubers were more or less covered with the hyphae. Eighty pounds of seed gave a return of 475 pounds of tubers, a

return of six pounds of tubers for every pound of seed planted. The tubers were all more or less covered with the sclerotia, but were not so badly scabbed as the tubers of the check plant. This plat gave a return of 36 sacks per acre.

Plat V—This was the poorest lot of seed, about 30% of the tubers failing to produce plants which reached the surface of the ground. The plants did poorly and many of those that reached the surface of the ground died before the close of the season. Thirty-five pounds of seed gave a return of 107 pounds of small, rough tubers,—a yield of a little over three pounds of tubers for every pound of seed planted, making a loss of 42%, a return of about 19 sacks per acre.

Results.—1. Success or failure in potato culture in this section of the state depends much upon the water supply.

2. The corrosive sublimate seed treatment gave no marked results when the treated seed was plantd on land which had been under cultivation for a number of years.

3. The formalin seed treatment gave a loss of 17% when such seed was planted on ground which had been under cultivation for a number of years.

4. Carefully selecting seed, free from sclerotia stage, gave a gain of 11%.

TABLE VI., SHOWING RESULTS OF EXPERIMENT NO. VI.

Plat Number	TREATMENT.	Number Pounds of Seed Potatoes Planted	Total Number of Tubers Harvested	Yield in Pounds for every Pound of Seed Tubers Planted	Gain or Loss	Yield in Sacks per Acre
I.	Check	140	767.30	5.33		32
II.	Treated with Corrosive Sublimate	101	539.50	5.34		32
III.	Treated with Formalin	105	466.50	4.44	17% Loss	27
IV.	Seed free from Sclerotia, but more or less covered with hyphae	80	475.50	5.94	11% Gain	36
V.	Cull Seed	35	107.70	3.08	42% Loss	19

Experiment VII—Rose Seedling seed was used in this experiment which was raised by the Agricultural Department from tubers bought on the market in the spring of 1901. Many of the tubers were covered with the hyphae and sclerotia of Corticium. This seed was planted on an old berry plantation, located on a knoll sloping toward the south and west. The soil is of a sandy loam, and has been well cultivated and manured during the past five years. It was plowed 8 inches deep in early spring and planted on May 6. The rows were planted 40 inches apart, the pieces being put at intervals of about 9 inches and 5 inches deep.

The plants of this experiment were sprayed three times with Bordeaux mixture. There was very little difference in the appearance of the plants in the various plats at any time during the season. The water was low in the ditch during the later part of the summer, so this field was irrigated but twice. The plants on the higher soil suffered some from sun scald. Altenaria was also found on some of the plants, but it apparently developed only on those which had an injured root system. The weight of a sack of tubers is estimated at 100 pounds.

Plat I Check—This seed was stored in the dugout all winter. Many of the tubers were more or less covered with the sclerotia of Corticium. The tubers were cut on May 5 and planted on the following day. These plants did quite well, but a number of diseased plants were observed in this plat

during the summer, and many diseased tubers were found in this plat at harvest time. It gave an average yield of 147 sacks of tubers per acre.

Plat II—This seed also contained many diseased tubers, but it was treated with corrosive sublimate one day before planting. The plants were five days late in reaching the surface of the ground. A few diseased plants were observed in this plat during the summer, but the tubers were clean, smooth and free from both scab and sclerotia. This plat gave a return of 213 sacks of tubers per acre, a gain of 66 sacks per acre.

Plat III—This seed was treated with corrosive sublimate on December 9th. After it became thoroughly dry it was again sacked and placed in the dugout until May 6th, when it was cut and planted. The plants were a week late in reaching the surface of the ground, but they did nicely and no diseased plants were observed in this plat. The tubers were clean, smooth and free from both scab and sclerotia. This plat gave a return of 160 sacks of tubers per acre, a gain of 13 sacks per acre over check.

Plat IV—This seed was taken from the dugout on December 9th, and treated with corrosive sublimate one hour and then placed on the floor until thoroughly dry, when it was sacked and placed in the dugout until May 5th, when it was again placed in a solution of corrosive sublimate for one hour. It was cut and planted on May 6th. The plants were 8 days late in reaching the surface of the ground. They did nicely, however, and no diseased plants were observed in this plat. The crop was clean, smooth and free from both scab and sclerotia. This plat gave a return of 143 sacks of tubers per acre, a loss of 4 sacks per acre over check.

Plat V—This seed was exposed to the light 23 days, five months before planting. It was then stored in the dugout until May 6th, when it was cut and planted. The plants reached the surface of the ground a few days in advance of those of the check plat. A number of diseased plans were observed in this plat, but no scab or sclerotia was observed on the tubers at harvest time. This seed gave a return of 196 sacks of tubers per acre, a gain of 49 sacks per acre.

Plat VI—This seed was stored in the dugout all winter. On May 5th all the stem ends were removed; otherwise the seed was treated like that of the check plat. No difference was noticed in the appearance of the plants in these two plats. Some of the tubers contained a few sclerotia at harvest time. This plat gave a return of 153 sacks of tubers per acre, a gain of 6 sacks per acre.

Results.—1. The standard corrosive sublimate treatment gave an increased yield of 45%. The tubers were larger, cleaner and better in every way.

2. Treating seed with corrosive sublimate five months before planting gave an increased yield of 9%. The tubers were also larger, cleaner and better than those of the check plat.

3. Treating the seed with a solution of corrosive sublimate, standard strength, one hour, five months before planting, and again one hour one day before planting, gave a loss of 2%, but the tubers were clean, smooth and free from disease.

4. Exposing the seed to the light 23 days five months before planting apparently increased the yield 35%.

5. Rejecting the stem end piece did not give marked results.

TABLE VII., SHOWING RESULTS OF EXPERIMENT NO. VII.

Plat Number.	TREATMENT.	Number Pounds of Seed Tubers Harvested	Total Number Pounds of Tubers Harvested	Yield in Pounds for every Pound of Tubers Planted	Gain or Loss	Yield in Sacks per Acre
I.	Check	111	1809	16.30		147
II.	Treated with Corrosive Sublimate 1 day before planting	90	2125	23.61	45% Gain	213
III.	Treated with Corrosive Sublimate 5 months before planting	109	937	17.77	9% Gain	160
IV.	Double Corrosive Sublimate Treatment	112	1783	15.90	2% Loss	143
V.	Seed Exposed to Light 23 days, 4 months before planting	104	2267	21.79	35% Gain	196
VI.	Stem End Rejected	89	1514	17.00	4% Gain	153

Experiment VIII—Rose Seedling seed was used in this experiment which was from the No. 1's of last year's experiment. It was planted on April 9th. The plants came up nicely and they were irrigated twice, still, most of them remained green until killed by frost. Some showed marked sun scald injuries early in the season, which were soon followed by early blight.

The field used in this experiment had been under cultivation for the past seven years. The soil is of a heavy clayey loam. This field has received very little manure during the past five years. The soil was too heavy for a desirable potato field.

Plat I Check—The largest tubers from last year's check plat were used for seed in this lot. Most of the plants remained green, but some of them had their subterranean parts badly injured and developed marked sun scald injuries. Three hundred and nine pounds of seed gave a return of 1,716 pounds of tubers, or 5½ pounds for every pound of seed planted.

Plat II—This seed was selected from the No. 1 of a lot which had been treated with formalin last year. They were treated with corrosive sublimate on April 30, and planted on May 9. These plants reached the surface of the ground about as soon as those of the check plat. No diseased plants were observed in this plat. Three hundred and thirty-four pounds of seed gave a return of 2,616 pounds of clean tubers, a yield of 7.8 pounds of tubers for every pound of seed planted, making a gain of 41% over check.

Plat III—This seed was selected from the No. 1's of last year's experiments. Only clean, round, smooth tubers were used. All long and all flat tubers were rejected. The soil of this plat was in a better condition than the soil of the other plats. No diseased plants were found in this plat, and the tubers were fully as clean and smooth as those of the treated lot. Two hundred and forty-six pounds of seed yielded 2,807 pounds of tubers, a return of 11½ pounds of tubers for every pound of seed planted, giving a gain of 106% over check.

Plat IV—Seed in this lot was selected from the various lots of last year's experiments. Only the long, smooth tubers were used. The plants were not so strong and vigorous as those of Plat III, but no diseased plants were observed in this plat. The tubers were all long, but only a few pointed ones were found at harvest time. One hundred and ninety-three pounds of seed gave a return of 1,283 pounds of tubers, a yield of 6½ pounds of tubers for every pound of seed planted, making a gain of 20% over check.

Plat V—This seed was selected from the No. 1's of the previous year's experiments. At least 20% of them had a few sclerotia of Corticium on them. Many diseased plants were observed in the plat and the crop was rough and

scabby. Two hundred and eighty-one pounds of seed gave a return of 1,531 pounds of tubers, a yield of 5½ pounds of tubers for every pound of seed planted, making a loss of 2%.

Plat VI—This seed was selected from the culls of last year's experiments. Only the round tubers were used. One hundred and seventy-five pounds of seed gave a return of 982 pounds of tubers, a yield of 5⅗ pounds of tubers for every pound of seed planted, an increase of 2% over check.

Results.—1. Treating diseased seed with corrosive sublimate, standard strength, increased the yield 41%.

2. Carefully selecting perfect shaped tubers gave a gain of 106% of smooth, round tubers.

3. Carefully selecting clean, long tubers gave a gain of 20%, but the tubers were all long and ill shaped.

4. Cull seed gave a loss of 2%. The tubers were rough and scabby.

5. Small, round seed gave a gain of 2% over check and the crop was fully as good in every way.

TABLE VIII., SHOWING RESULTS OF EXPERIMENT NO. VIII.

Plat Number	TREATMENT	Number Pounds of Seed Tubers Planted	Total Number of Pounds of Tubers Harvested	Yield in Pounds for every Pound of Seed Planted	Gain or Loss	Yield in Sacks per Acre
I.	Check	309	1716	5.55		39
II.	Corrosive Sublimate, 1 oz. to 8 gallons of water	334	2616	7.83	41% Gain	55
III.	Large Selected Seed	246	2807	11.41	106% Gain	80
IV.	Long Pointed Seed	193	1283	6.64	20% Gain	46
V.	Diseased Seed	281	1531	5.44	2% Loss	38
VI.	Small Round Seed	175	982	5.61	2% Gain	39

Experiment IX—These experiments were conducted in a field which had been planted in currents during the previous four years. It slopes toward the west and the soil is a heavy clay, but it has been well manured and cultivated for a number of years. It was plowed 8 inches deep in early spring and on May 6th planted with Rural New Yorker seed. These tubers were exceptionally clean. They were taken from a lot of tubers which was raised from mountain seed in 1901 by the Agricultural Department. The rows were planted 40 inches apart, the pieces being placed at intervals of 15 inches, and 5 inches deep. The plants in this experiment came up uniformly, and were all sprayed three times with Bordeaux mixture, which kept their foliage in good condition until killed by frost on the night of September 11th.

The water was unusually low in the ditch during the latter part of the season, consequently the plants in all of these plats suffered more or less from lack of moisture. All the plats were watered twice excepting Plat V, which was watered three times. The return from this plat shows plainly that if the field had been properly watered the yield would have been much larger. The plants in this experiment were carefully watched during the entire season, and we observed only a few diseased plants in these plats. The tubers were clean, smooth and free from scab.

Plat I Check—The seed in this lot was taken from the dugout on December 9th and was placed in water two hours and then placed on the floor

of the Horticultural Building until thoroughly dry, when it was sacked and placed in the dugout. On May 6th it was cut and planted. The plants came up nicely and remained strong and vigorous all the season, giving an average yield of 142 sacks per acre of clean, smooth tubers.

Plat II—This seed was treated with a solution of one ounce corrosive sublimate to eight gallons of water on December 9th. After the tubers had been soaked one hour they were placed on the floor until dry, when they were sacked and stored in the dugout. On May 5th they were again treated with corrosive sublimate for one hour and cut and planted on the following day. The plants were a little later in reaching the surface of the ground, but six weeks later they were fully as large and vigorous as those of the check plat. No diseased plants or tubers were found in this plat. This plat gave an average yield of 144 sacks per acre of clean, smooth tubers, a gain of 2 sacks per acre over check.

Plat III—The seed in this plat was taken from the dugout on December 9th, and treated two hours with a solution of eight ounces of formalin to sixteen gallons of water. The tubers were then placed on the floor until the following day, when they were sacked and placed in the dugout until May 6th, when they were cut and planted. The plants reached the surface of the ground on time, and were strong and vigorous until killed by frost. No diseased tubers were observed when the crop was harvested. This plat gave a gain of 13 sacks per acre, but this gain was probably due to seepage water from the lawn thoroughly soaking six of the rows on the night of August 3rd. These tubers were unusually good.

Plat IV—This seed was taken from the dugout on December 7th, and placed on the basement floor of the Horticultural Hall, where it was fully exposed to the light On the 30th of December it was again sacked and placed in the dugout. On May 6th it was taken out, cut and planted. These plants reached the surface of the ground possibly a little in advance of the check, but they showed no marked gain over the the check plants at any time. This plat gave an average yield of 144 sacks to the acre of clean, smooth tubers, a gain of two sacks per acre over check.

Plat V—This seed was selected and treated just the same as that of the check plat, but the plants were carefully irrigated three times. No diseased plants or tubers were taken from this plat. The plants remained green and vigorous until killed by frost. This plat gave an average yield of 197 sacks per acre of good, large tubers, a gain of 55 sacks per acre over the check.

Results.—1. Dipping clean, healthy seed tubers in a solution of corrosive sublimate, standard strength, for one hour, five months before planting, and again for one hour just before planting, apparently had no influence on the seed when such seed was planted in new ground.

2. Clean, healthy seed treated in a solution of eight ounces of formalin to sixteen gallons of water for two hours, five months before planting, gave no marked result when such seed was planted in new ground.

3. Exposing clean, healthy seed to the light 23 days, five months before planting, gave no marked results.

4. Three thorough waterings gave 38% larger returns than two waterings.

TABLE IX., SHOWING RESULTS OF EXPERIMENT NO. IX.

Plat Number	TREATMENT	Number Pounds of Seed Tubers Planted	Total Number of Pounds of Tubers Harvested	Yield in Pounds for every Pound of Seed Planted	Gain	Number of Sacks per Acre
I.	Check, irrigated two times	64	1298½	20.29		142
II.	Corrosive Sublimate, 1 hr., 12-9-01, again 5-5-02, Irrig'td. twice	105	2167	20.63		144
III.	Treated with Formalin 2 hrs. 12-9-01. Irrigated 2 times	115	2554	22.20	9%	155
IV.	Seed exposed to light 23 days. Irrigated 2 times	70	1437	20.52		144
V.	Check, Irrigated 3 times	33	988	28.11	39%	197

Experiment X—The seed in the following experiment was taken from the Rural New Yorker No. 1's of last year's experiments. It was planted on heavy, clayey ground which had been a plum orchard for a number of years, but it had been well cultivated and manured during the previous five years. The water supply in the ditch gave out early in the season and the field received but two waterings.

The ground was plowed eight inches deep in the early spring and the seed was planted five inches deep. The plants came up nicely and their foliage remained green until killed by frost.

Plat I—Check—The tubers of this lot were smooth and clean, not a scabby or diseased tuber was observed in the lot. The plants were strong and healthy. Three hundred and forty-eight pounds of seed gave a return of 3,042 pounds of clean, round tubers, a yield of 8.7 pounds of tubers for every pound of seed planted.

Plat II—The seed from which these tubers grew was treated with corrosive sublimate and this seed was also treated with corrosive sublimate. It was an evcellent lot of seed. The plants were strong and vigorous and the foliage remained perfect until killed by frost. Three hundred and sixty-three pounds of seed gave a return of 3,429 pounds of tubers; 9.44 pounds of tubers for every pound of seed planted, a gain of 8½%.

Plat III—All the long and flat tubers were rejected from this lot, only the clean, round and perfect shaped tubers were used. Two hundred and seventy pounds of seed gave a return of 3,141 pounds of tubers, a yield of 11.63 pounds of tubers for every pound of seed planted, making a gain of 33⅓% over check.

Plat IV—The tubers in this lot were taken from the No. 1's of last year's crop, but all of them were ill-shaped and more or less scabby. Two hundred and fifty pounds of seed gave a return of 1,559 pounds, a yield of 6.24 pounds of tubers for every pound of seed planted, giving a loss of 28% when compared with check.

Results.—1. Good, healthy seed treated with corrosive sublimate and planted in new soil gave a gain of 8½%.

2. Carefully selected seed gave a gain of 33⅗%.

3. Selecting all the poorest shaped, scabby and diseased seed and planting it on new ground gave a loss of 28⅕%.

4. The difference between best and poorest seed being 62%.

TABLE X., SHOWING RESULTS OF EXPERIMENT NO. X.

Plat Number	TREATMENT	Number Pounds of Seed Tubers Planted	Total Number Pounds of Tubers Harvested	Yield for Every Pound of Seed Planted	Gain or Loss	Yield in Sacks per Acre
I.	Check	348	3042	8.70		60
II.	Corrosive Sublimate, 1 oz. to 8 gals. of water	363	3429	9.44	8½% Gain	66
III.	Good Selected Seed	270	3141	11.63	33⅗% Gain	81
IV.	Poor Selected Seed—Culls	250	1559	6.24	28⅕% Loss	44

Experiment XI—These experiments were undertaken in 1903 to test the value of selecting seed and the value of treating inferior seed with corrosive sublimate solution. An exceptionally badly diseased lot of Rural New Yorker seed was secured for this test. These experiments were planted on an old plum orchard containing a heavy, clayey soil, but it had been well manured and cultivated for the past five years. The soil was plowed eight inches deep in early spring and the seed was planted four inches deep on April 9th. The plants did poorly from the first. The water was turned out of the main ditch during the fore part of the season so the field was irri-

gated but twice. The runs were only about four inches deep, making it impossible to supply the water properly.

Plat I—Check—These tubers were rough and scabby and all of them were more or less covered with the hyphae and sclerotia of Corticium. The plants came up very unevenly and 32% of this seed failed to produce plants which reached the surface of the ground, Seventeen per cent. of those that grew, developed small worthless tubers. Only 57% of the seed planted produced plants which developed large tubers, and these were scabby and of a poor quality. On July 24th the plants in this plat were carefully examined and it was observed that 55% of the plants had their main stems covered with the fruitage stage of this fungus. Three hundred and twenty-five pounds of seed gave a return of 1,240 pounds of tubers. A yield of 3⅘ pounds of tubers for every pound of seed planted. A return of 23 sacks to the acre.

Plat II—This seed, like that used in the Check plat, was scabby and more or less covered with the hyphae and sclerotia. It was treated with corrosive sublimate, standard strength, seven days before it was planted. These plants were about eight days later than those of the Check plat and they also came up very unevenly. Twenty-six per cent. of the seed failed to produce plants which reached the surface of the ground. Ten per cent. of those that grew failed to develop large tubers. Only 67% of the seed planted developed salable tubers. They were clean and quite free from scab. Fifteen per cent. of the plants in this lot showed traces of the fruiting stage. Two hundred pounds of seed gave a return of 1,080 pounds of tubers. A return of 5⅖ pounds of seed for every pound of seed planted. Giving a gain of 41% over Check, or about 32 sacks to the acre.

Plat III—This seed was carfeully selected. All tubers containing sclerotia were rejected. However, many of these were rough and scabby, and all of them were more or less covered with the hyphae. These plants also came up very unevenly. Seventeen per cent. of the seed planted failed to produce plants which reached the surface of the ground. Twenty-eight per cent. of those that reached the surface failed to develop normal tubers. Seventy per cent. of this seed produced plants which developed fair-sized tubers. These tubers were rough and more or less covered with both hyphae and sclerotia. Twenty per cent. of the plants showed traces of the fruiting stage. One hundred and fifteen pounds of seed produced 497 pounds of tubers. A return of 4 8-25 pounds for every pound of seed planted. The yield being nearly the same as that of the Check.

Results.—1. Diseased tubers are frequently prominent factors in producing crop failures.

2. The fruiting stage of this fungus apparently develops more freely on plants grown from tubers containing many sclerotia.

3. Carefully selecting seed free from sclerotia, but more or less covered with the hyphae of this fungus did not check its injuries to any marked extent, but the fruiting stage of the fungus developed less freely on the plants from the selected seed.

4. The standard corrosive sublimate treatment apparently checks the development of this disease when the treated seed is planted in new soil.

TABLE XI., SHOWING RESULTS OF EXPERIMENT NO. XI.

Plat Number	TREATMENT	Number Pounds of Seed Tubers Planted	Total Number Pounds of Tubers Harvested	Yield for Every Pound of Seed Planted	Gain	Yield in Sacks per Acre
I.	Check	325	1240	3.81		23
	Treated, Corrosive Sublimate 1 oz. to 8 gals. of water, 1½ hrs.	200	1080	5.40	41%	32
	Selected free from Sclerotia	115	497	4.32	13%	26

Bulletin 92 October, 1904

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Large Potato Vines and No Potatoes

...BY...

WENDELL PADDOCK

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado
1904

The Agricultural Experiment Station

FORT COLLINS, COLORADO

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*Large Potato Vines and No Potatoes

By Wendell Paddock.

This bulletin contains a condensed account of our work with potato diseases, the most of which has appeared in Bulletins 70 and 91 of this station, and its purpose is to supply information to the increasing number of correspondents who are becoming interested in potato growing. It is addressed primarily to those farmers who live outside of the successful potato-growing sections, but the best potato soils are by no means free from the troubles that are described below. By having a correct understanding of certain peculiar conditions of the potato plant, which have been ascribed to various causes, such as water, alkali, altitude, etc., it is possible that the most successful grower can modify his system of culture to advantage.

Most farmers who have tried to grow potatoes in this state and failed, or who have been only partially successful, will be familiar with the following conditions:

Good vines with no tubers or a cluster of small, worthless tubers; in many instances, even in the best potato soil, the plants fail to come up, or weak plants are produced, which die before the potatoes are mature, thus resulting in a poor stand; potato blight, or the dying of a portion or all of the vines; russeted and scabby potatoes; blight and scab also seen in the best potato districts; and finally, collar rot or black ring of the vine, at the surface of the ground.

Experiments have proven that any and all of these conditions can be produced by the action of a certain plant disease, and observations in many parts of the state show that this fungus is abundant, and is undoubtedly responsible for most of the lack of success in potato growing.

Nature of the Disease. This fungus (*Corticium vagum* B. & C. var. *Solani,* Burt.) appears to grow naturally in this state, as it is found in the remote and newer parts, and it also attacks a number of plants other than the potato, both cultivated and wild. After the soil has become infected the fungus persists for a long time.

If the fungus is not already present, the soil will soon become infected after potatoes have been grown. This is true for the rea-

*Bulletins 70 and 91, by F. M. Rolfs, being technical in character, have not been sent to the general mailing list. Copies will, however, be sent on request.

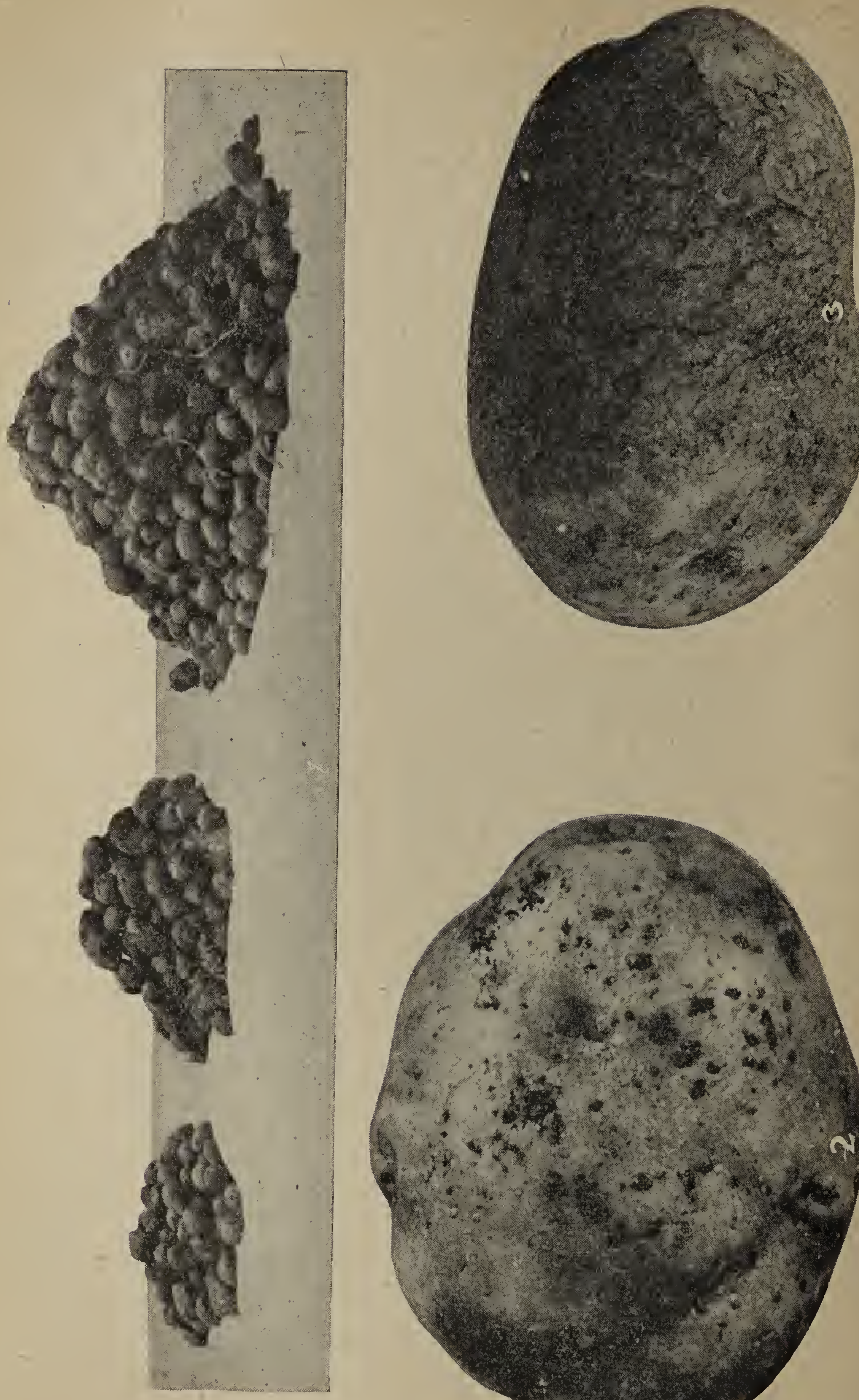

PLATE I.

son that it is difficult to find a sack of potatoes free from all traces of the disease. It lives over winter in the cracks of rough and russeted potatoes and in the ulcers of scab, and also in what appears to be patches of dirt which stick closely to the surface of the potato. By looking closely at these dirt-like appearing objects, which are well shown in Fig. 2, Plate I., it will be seen that they are not composed of ordinary soil. In fact, they are made up of the closely interwoven root-like organs of the fungus.

This tiny plant also produces an abundance of seed-like bodies or spores which help to spread it. They are borne only on green potato vines and just above the surface of the ground. Here a thin, delicate layer is formed that looks like a slight deposit of alkali, and the spores are borne on the tips of the threads of which it is composed.

A Poor Stand of Potatoes. When diseased potatoes are used for seed, or when clean potatoes are planted in infected soil, the fungus starts into growth with the young potato plant. The tender shoots are often attacked, with the result shown in Plate II. On the right are two shoots, which were rotted off by the fungus before they reached the surface of the ground. This illustrates how a poor stand of potatoes is often brought about. The other two were badly injured and might have become mature plants, but affected with the familiar collar rot or black ring.

Vines and no Tubers. The most damage is done, however, by cutting off the tuber stems, and this portion of the potato plant is especially liable to attack. These stems are often cut off as fast as they grow out, thus leaving no place on which tubers may form. But in some instances a cluster of small or "Little Potatoes" form around the main stem, seemingly the result of girdling by the fungus.

Potato Scab. The potato tubers are often made rough and scabby by the growth of the disease on their surfaces. (Plate I., Fig. 3.) All gradations of these injuries may be found, from a rough or russeted appearance to deep scabs or ulcers that greatly injure the appearance of the potato. Singularly enough, scab is more common in the best potato soil than it is in localities where the crop is precarious. Sandy or gravelly soils, when first brought under cultivation, often give a large per cent. of scabby potatoes, but after one or more crops of alfalfa have been plowed under, this tendency is partially corrected.

Potato Blight. Potato blight, or the dying of the leaves and vines before the crop is mature, is commonly thought to be entirely due to diseases which attack the top of the potato plant. We have not found it so in Colorado. Spraying experiments with Bordeaux

PLATE II.

mixture did not materially lessen the blight, and the microscopic plants which cause these leaf diseases are not commonly found associated with this trouble. We conclude, therefore, that the premature dying of the potato vines is usually an evidence that the underground parts have been severely injured by the fungus in question.

Running Out. The running out of potatoes, as it is called when the tubers become pointed or much elongated, appears also to be associated with the attacks of this fungus. But just what the relation is between the two has not yet been determined.

Treating the Seed. At first thought it would appear to be a simple matter to combat this disease by treating the seed with formalin or corrosive sublimate. In fact, some of our experiments with treated seed have shown decided gains, but others have given a loss. The results of this season are again negative, so it is doubtful if the seed treatment can be made to pay. This is true for the reason that most Colorado soils are thoroughly infected with the fungus and the treatment usually delays the sprouting of the seed and consequently injures the plant so that it does not yield as well as untreated seed.

Seed Selection. Better results have been secured by selecting smooth, round seed that was entirely free from disease. Such potatoes are not only free from disease, but the chances are that they were grown on vines that were not seriously affected by the fungus as run out potatoes usually occur on diseased vines. We would expect such seed to show a certain degree of resistance to the disease.

Disease-Resistant Varieties. The only prospect that we now have of ever overcoming this disease beyond what can be done by improved methods of culture, is to select seed from the healthiest plants that produce good shaped tubers, and thus gradually breed up a resistant strain. Last year over 80 varieties of potatoes were grown in the College garden in soil that was known to be badly diseased. Only 20 kinds out of this number were saved for further testing; the rest produced only a few small, misshapen tubers, and many of the vines bore none at all. This year the list has been still further cut down, though a few varieties yielded well. These were all dug by hand, and the hills that produced the best tubers have been saved for further testing. We hope in time to build up a strain of potatoes that will resist the attacks of this fungus by selecting from individual hills that are the least attacked by disease.

Not many potato growers can afford the time to follow up experiments of this kind, but a less rigid method of selection could be practiced by all. The following is quoted from Bulletin 91, of this Station:

"Another method which gives evidence of considerable practical value is to set aside each year five or ten acres of land for the growing of seed

potatoes. The soil of such tract ought to be fertile and free from the various diseases which attack the potato plant. The tubers used in planting the seed tract are carefully selected each year from the seed plat of the previous year. The surplus seed is used for planting the gneral crop, and in this way a stain of pedigree potatoes is gradually developed."

Culture. The best potato soil is a sandy or gravelly loam which contains an abundance of vegetable matter, and which is well underdrained. In the Greeley district the soil will average about four feet deep. Below this is an immense layer of gravel, which insures perfect drainage. Vegetable matter is secured by plowing under alfalfa sod. Alfalfa is grown two years, then turned under in the spring and planted to potatoes. Two crops of potatoes are grown in succession, then wheat is sown and the land again seeded to alfalfa, thus making a five-year rotation. The second crop of potatoes, however, is rarely as good as the first, probably because of the increase of the fungus in the soil, and in most localities but one crop of potatoes should enter into the rotation system.

A heavy alkaline soil, that has poor underdrainage, furnishes an ideal condition for the growth of this plant disease, and it is in such soils that potato failures are most frequent. But poor underdrainage in any soil is conducive to its growth. It will be seen, then, that cultivation and irrigation must be important factors in controlling the disease. Most people who attempt to grow potatoes make the mistake of using more water than is necessary for the best growth of the plants. The rows should be comparatively short, so that part of the ground will not need to be over-watered. The seed should be planted about four inches deep in rows 38 to 40 inches apart. The furrows should be about five inches deep for the first irrigation, and with subsequent irrigations they should be increased in depth. The idea is to make the furrows deep enough to supply sufficient moisture to the roots without saturating the upper portion of the ridge where the tubers form. Cultivation should follow as soon after as the ground is in condition to work. The condition of the soil and plants should always govern the amount and the frequency that water is applied.

After all has been done in the way of culture, seed selection and a long rotation of crops, the vines and weeds should be collected and burned each season after the potatoes have been dug. This will destroy a great deal of the fungus that would infect other fields, as the vines are scattered by various means.

Bulletin 93 December, 1904

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado

Colorado Hays and Fodders.

ALFALFA—TIMOTHY—NATIVE HAY—CORN
FODDER—SORGHUM—SALT BUSH.

DIGESTION EXPERIMENTS

—BY—

WILLIAM P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1904.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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DIGESTION EXPERIMENTS WITH SOME COLORADO HAYS AND FODDERS.

BY WM. P. HEADDEN.

Some years ago, while making a study of the alfalfa plant and again on extending the work to a study of alfalfa and some other hays, I was surprised at the scarcity of data upon the digestibility of the various hays that I was endeavoring to study. The results of the experiments that I succeeded in finding were not only few in number but not concordant. Further, they were made with hays which could scarcely be compared with those that I was studying and under different conditions from those which obtain here.

It is accepted as a fact among us, whether justly so or not, that alfalfa or lucerne hay as grown and made in this state is scarcely excelled by any other hay for the purposes of milk-producing and fattening, for which it is used in large quantities. It is also probably true that the alfalfa grows as well under our conditions and makes as good a quality of hay as in any other locality in this country and perhaps in the world. It is for such reasons that it seemed to me desirable to make some experiments to determine anew the digestion coefficients of alfalfa hay produced here. It is true that these had been previously determined by my immediate predecessor, Dr. O'Brine, using steers to experiment with, but I wished to extend the experiments to include some other fodders. I deemed it desirable that still others should be added, because the accumulated data on this subject is neither extensive nor concordant. I therefore present the results of some experiments on the digestibility of some Colorado grown fodders, using sheep as our experimental animals.*

In Bulletin No. 39, I tried to set forth some of the differences between hays made from leguminous plants and the grasses. I have this problem in view in these experiments also, but rather incidentally, the principal purpose of this bulletin being to give the results of our attempts to determine the digestion coefficients

*I wish to acknowledge the patient, faithful, cheerful, and interested service rendered by my assistants in the prosecution of this work. Some of my results being unusually low led to frequent repetitions as a matter of precaution. Some of the work too has been disagreeable, but my assistants have at all times done it willingly. It is with pleasure that I make this acknowledgment.

of some of our fodders, either because of their present importance or because of their possible interest to stockmen and feeders.

It may not be amiss to state some of the more salient differences between the leguminous hays and those made from grasses. The leguminous hays contain a larger portion soluble in water and alcohol by about 10 per cent than the native hay, the amount of hemicellulose, cellulose like constituents reacting with phloroglucin, is much larger in the leguminous hays than in the native hays. These two facts may account for the greater sensitiveness that the leguminous hays show to the effects of moisture. I have seen alfalfa badly discolored by a heavy dew. These facts, too, may indicate even greater differences than we at present realize. The extractive as well as the nitrogenous substance are probably quite different, which is also certainly true among the grasses as well.

The leguminous hays are as a class sensitive to the action of water and inclined to heat readily. Under our Colorado conditions the action of water is often wholly avoided and the hay has a bright green color and a marked pleasant odor. One would expect such hay to be more uniform in quality and superior to that made in states where it is difficult to cut and cure the hay without its being more or less damaged by rains or heavy dews.

I do not know to what extent the quality of the hay affects its digestion coefficients, but alfalfa hay is certainly sensitive to the action of even a slight amount of moisture in the form of rain or dew. I have but little data conveying any idea of how sensitive it is or of the character of the changes produced in it. I have had opportunity to study but one sample in any detail; in this case I do not know what percentage of the original hay was washed out, the hay did not heat; it was simply cut at one of those inopportune periods when it rains every few hours even in Colorado. The total rainfall during this wet period was 1.76 inches. The hay which escaped the rain contained 26.46 per cent crude fibre; that which was exposed to it contained 38.83 per cent, the former contained 18.71 per cent protein the latter 11.01. The nitrogen free extract, which includes the hemicelluloses was reduced about five per cent. These statements and figures may serve both to justify and explain my statement that legume hay, especially alfalfa, is very sensitive to the action of moisture and fermentation. In the case of brennheu, the fermentation seems to make it more palatable to cattle. I have never heard of this effect having been produced in the case of hays made from grasses, this, however, may be the case, but I have not met with any statement to this effect. The large portion of the legume hays soluble in water and easily fermentable accounts for their rapid deterioration when exposed to excessive moisture and heat. The amount

dissolved by alcohol and cold water from alfalfa hay is about 36 per cent, while the same menstruua dissolve only 27 per cent from native hay and 28 from timothy.

In the case of native hay, the results will doubtlessly vary with the different amounts of the various grasses which make up the hay. A hay consisting of blue stem principally will differ from one made up of a mixture of grasses, and probably still more from one consisting largely of sedges. This consideration should not be lost sight of when any statement concerning a native hay is made, for the statement may be based upon results obtained in experiments with a hay very different from the one the reader may have in mind. The mixture of grasses represented by the term native hay, is indicated by the sample used in Bulletin 39, in which we find the following: *Andropogon scoparius*, *Carex marcida*, *Elymus canadensis*, *Panicum virgatum*, *Sporobolus asperifolius*, *Sporobolus cryptandrus*, *Poa tennuifolio*, *Andropogon furcatus*, *Chrysopogen avenacrus*, *Calamovilfa longifolio*, *Agropyron tenerum*, and *Bouteloua oligostachya*. This mixture represented an excellent sample of this class of hay, but results obtained with it can only in a measure be applied to another hay representing a different mixture of grasses, i. e., to one consisting almost wholly of blue stem, *Agropyron tenerum*, or rushes and sedges.

I recognize the necessity of having a representative sample of hay, even when the hay is composed exclusively of one plant, which is the case in the alfalfa hay, and for this reason alone I make the following statements:

The sample of alfalfa hay used was furnished by the Farm Department. The practice is, when possible, to cut the alfalfa before it is more than in half bloom, and this hay was probably cut when the alfalfa was in this condition, but the analysis agrees better with the composition of a hay cut at a later period, i. e., when in full bloom or even past this stage. The hay was not first class hay.

The results obtained with this sample were so exceptional, especially in regard to the ether extract or fat, that the analytical work was repeated in the case of the hay and the feces of sheep No. 3. The principal weakness in my data lies in the sample of hay itself, which is quite normal in its composition except in regard to the amount of ether extract or so called fat that it contains, of which there is even a little less than I have heretofore found in the stems or in hay made from plants in full seed. The protein, 13.12 per cent, is a shade low, and the crude fibre 41.05 per cent, a trifle high for really good alfalfa hay, but they are not abnormal enough to justify their rejection. The ether extract, however, being less than one half the amount usually found in

average samples of alfalfa hay is open to serious doubt. The feces voided by sheep feeding on this hay are, on the other hand quite as rich in ether extract as those of sheep which had been feeding on much better hay.

The case presents itself to me in the following light, as it will probably present itself to others, i. e., if the feces of two sets of sheep feeding on the same kind of hay show practically the same amount of the ether extract, we ought to find a corresponding agreement in the amount of ether extract in the respective hays, provided the digestive processes have acted upon them in the same manner and degree. But we do not find this to be the case, and I view the discrepancy as of such importance that I consider it my duty to reject this series of experiments with alfalfa hay or to give the results obtained and a fuller account of the study made in our endeavor to find the error, or some explanation for the results obtained. I shall give the series with all results as found and then an account of the work done.

The digestion coefficient for the ether extract seems to be the only one concerning which any serious question can be raised. The coefficient obtained being negative cannot be used, but it seems to me that there must be some facts indicated by this result, for, though the agreement of the coefficients found is very poor, they agree in their general purport, i. e., they are all three negative. The hay seems to have undergone some change which lessened the amount of ether extract in the hay, but in passing through the digestive processes it appears to have been rendered soluble again. This can scarcely be the case. The excess is more likely due to ether soluble substances in the feces which are not furnished by the undigested portions of the hay.

The sheep used in the first four series of experiments were wethers between three and four years old.

The fodders used were corn fodder, native hay, timothy hay and alfalfa hay.

The animals were fed for a period of twelve days and the feces collected during the last five days.

CORN FODDER.

Fodder Fed.—Sheep No. 3.

Weight of fodder received in five days, 5395.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.*	Extract.
7.02	11.11	1.36	8.66	32.37	39.48

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5016.27	599.38	73.37	467.20	1746.36	2129.95

**Orts, air dried, weighed 606.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.71	24.18	1.28.	8.36	31.25	28.28

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
565.34	146.53	7.76	50.66	189.37	171.38

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5016.27	599.38	73.37	467.20	1746.36	2129.95
Less orts	565.34	146.53	7.76	50.66	189.37	171.38
Consumed	4450.93	442.85	65.61	416.54	1556.99	1958.57

Feces.

Air dried feces weighed 1965.5 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.11	13.73	1.86	10.89	24.22	42.20

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1825.75	269.86	36.56	214.04	478.04	829.34

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4450.93	442.85	65.61	416.55	1556.99	1958.57
Voided	1825.75	269.86	36.56	214.04	478.04	829.34
Digested	2625.18	172.99	29.05	202.51	1078.95	1129.23
Co-efficients or percentages digested	**58.98**	**39.06**	**44.28**	**48.62**	**69.30**	**57.66**

*Fibre is used throughout these tables for crude fibre, and extract for nitrogen free extract.

**Orts is the portion left by the animal.

CORN FODDER.

Fodder Fed—Sheep No. 5.

Weight of fodder received in five days, 5395.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.02	11.11	1.36	8.66	32.37	39.48

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5016.27	599.38	73.37	467.20	1746.36	2129.95

Orts, air dried, weighed 453.5 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.02	23.07	1.56	8.70	30.47	29.18

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
421.65	104.62	7.07	39.45	138.18	132.33

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5016.27	599.38	73.37	467.20	1746.36	2129.95
Less orts	421.65	104.62	7.07	39.45	138.18	132.33
Consumed	4594.62	494.76	66.30	427.75	1608.18	1997.62

Feces.

Air dried feces weighed 1978.5 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.76	14.43	1.83	11.66	24.19	40.13

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1825.00	285.50	36.20	230.69	478.59	793.97

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4594.62	494.76	66.30	427.75	1608.18	1997.62
Voided	1825.00	285.50	36.20	230.69	478.59	793.97
Digested	2769.62	209.26	30.10	197.07	1129.59	1203.65
Co-efficients or percentages digested	**60.28**	**42.29**	**45.40**	**46.07**	**70.24**	**60.25**

CORN FODDER.

Fodder Fed.—Sheep No. 10.

Weight of fodder received in five days, 5395.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.02	11.11	1.36	8.66	32.37	39.48

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5016.27	599.38	73.37	467.20	1746.36	2129.95

Orts, air dried, weighed 500.50 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.33	18.89	1.40	10.03	30.00	34.35

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
473.82	94.55	7.01	50.21	150.12	167.96

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5010.27	599.38	73.37	467.20	1746.36	2129.95
Less orts	473.82	94.55	7.01	50.21	150.12	167.96
Consumed	4542.45	504.83	66.36	416.99	1596.24	1961.99

Feces.

Air dried feces weighed 2115.50 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.43	12.63	1.63	10.36	27.11	41.82

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1979.36	267.19	34.48	219.11	573.57	884.85

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4542.45	504.83	66.36	416.99	1596.24	1961.99
Voided	1979.36	267.19	34.48	219.11	573.57	884.85
Digested	2563.09	237.64	31.88	197.88	1022.67	1077.14
Co-efficients or percentages digested	**56.43**	**47.08**	**48.04**	**47.46**	**64.07**	**54.90**

Average Coefficients, as Given by the Three Sheep.

	Dry Matter.	Ash.	Fat.	Protein.	Crude Fibre.	N. Free Extract.
Sheep No. 1	**56.43**	**47.08**	**48.04**	**47.46**	**64.07**	**54.90**
Sheep No. 2	**60.28**	**42.29**	**45.40**	**46.07**	**70.24**	**60.25**
Sheep No. 3	**58.98**	**39.06**	**44.28**	**48.62**	**69.30**	**57.66**
Average	**58.56**	**42.84**	**45.91**	**47.38**	**67.87**	**57.60**

The corn fodder used was a dent corn, sown broadcast and cut quite immature; some of the plants were in silk, but no corn was formed on the ears. The fodder was about eight months old when fed.

NATIVE HAY.

Fodder Fed.—Sheep No. 2.

Weight of fodder received in five days, 5380.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.23	7.33	2.05	7.36	35.78	41.70

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5044.88	394.35	110.29	394.32	1924.10	2243.22

Orts, air dried, weighed 429.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.85	8.77	1.70	7.21	38.17	38.29

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
403.91	37.62	7.29	30.93	163.72	164.21

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5044.88	394.35	110.29	394.32	1924.10	2243.22
Less orts	403.91	37.62	7.29	30.93	163.72	164.21
Consumed	4640.97	356.73	103.00	363.39	1760.38	2079.01

Feces.

Air dried feces weighed 1832.5 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.06	10.16	2.68	7.11	35.93	39.06

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1721.50	186.12	49.11	130.21	658.47	715.71

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4640.97	356.73	103.00	363.39	1760.38	2079.01
Voided	1721.50	186.12	49.11	130.21	658.47	715.71
Digested	2919.47	170.61	53.89	233.18	1101.91	1363.30
Co-efficients or percentages digested	**62.91**	**47.82**	**52.32**	**67.47**	**62.59**	**65.57**

NATIVE HAY.

Fodder Fed.—Sheep No. 5.

Weight of fodder received in five days, 5380.0 grains.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.23	7.33	2.05	7.36	35.78	41.70

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5044.88	394.35	110.29	394.32	1924.10	2243.22

Orts, air dried, weighed 553.5 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.30	8.34	1.53	6.98	38.31	38.54

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
518.63	46.16	8.47	38.63	212.02	213.35

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5044.88	394.35	110.29	394.32	1924.10	2243.22
Less orts	518.63	46.16	8.47	38.63	212.02	213.35
Consumed	4526.25	348.19	101.82	355.69	1702.08	2029.87

Feces.

Air dried feces weighed 1968.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.58	10.46	2.74	7.68	32.43	40.14

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1838.59	205.82	53.92	151.12	638.23	789.91

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4526.25	348.19	101.82	355.69	1702.08	2029.87
Voided	1838.59	205.82	53.92	151.12	638.23	789.91
Digested	2687.66	142.37	47.90	204.57	1063.85	1239.96
Co-efficients or percentages digested	**59.38**	**40.89**	**47.14**	**57.51**	**62.50**	**61.08**

NATIVE HAY.

Fodder Fed.—Sheep No. 10.

Weight of fodder received in five days, 5380.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.23	7.33	2.05	7.36	35.78	41.70

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5044.88	394.35	110.29	394.32	1924.10	2243.22

Orts, air dried, weighed 433.5 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.09	6.44	0.96	5.37	36.98	44.16

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
407.10	27.91	4.16	23.27	160.31	191.43

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5044.88	394.35	110.29	394.32	1924.10	2243.22
Less orts	407.10	27.91	4.16	23.27	160.31	191.43
Consumed	4637.78	366.44	106.13	371.05	1763.79	2051.79

Feces.

Air dried feces weighed 2130.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.48	10.14	2.90	7.37	33.97	39.14

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1991.96	215.91	61.77	156.91	723.52	833.61

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4637.78	366.44	106.13	371.05	1763.79	2051.79
Voided	1991.96	215.91	61.77	156.91	723.52	833.61
Digested	2645.82	150.53	44.36	214.14	1040.27	1218.18
Co-efficients or percentages digested	**57.05**	**41.24**	**41.80**	**57.71**	**58.98**	**59.37**

The Average Coefficients found for Native Hay.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 2	**62.91**	**47.82**	**52.53**	**67.47**	**62.59**	**65.57**
Sheep No. 5	**59.38**	**40.89**	**47.14**	**57.51**	**62.50**	**61.08**
Sheep No. 10	**57.05**	**41.24**	**41.80**	**57.71**	**58.98**	**59.37**
Average	**59.78**	**43.32**	**47.09**	**60.90**	**61.36**	**62.01**

Jordan and Hall give a blue joint under meadow grasses. I do not know whether this is our blue joint or not, but for this they give the following coefficients:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Maximum	68.6	48.7	52.3	70.2	72.4	68.6
Minimum	39.9	10.0	37.0	56.5	36.5	43.2
Average	54.3	29.4	44.7	63.4	54.5	55.9

This blue joint is probably *Calamagrostis canadensis*, while our blue stem is *Agropyron tenerum*. I know of no data on this subject applicable to our native hay, unless the comparison be made under the very broad head of meadow hay, which is, perhaps, a little too broad.

The native hay used in this experiment was purchased in the market as "upland hay." It was said to have been cut on the farm of Mr. Gilkison and was composed largely of blue joint *Agropyrum tenerum*.

I do not think that the coefficients of digestion of this class of hay have been determined, at least I can find none.

Such hay is cut from the bottom lands along the water courses, or where water courses have been and the supply of moisture is both greater and more constant than in the higher ground. It can scarcely be compared with Eastern meadow hay, though such a comparison would, in a measure, be justified.

TIMOTHY HAY.

Fodder Fed.—Sheep No. 3.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.58	7.21	1.43	7.45	40.71	36.52

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5166.19	398.77	79.08	411.91	2251.31	2019.18

Orts, air dried, weighed 000 grams.

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5166.19	398.77	79.08	411.91	2251.38	2019.18

Feces.

Air dried feces weighed 2349.50 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.07	11.10	2.49	7.45	41.85	32.04

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2230.35	260.71	58.51	175.03	983.22	752.71

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5166.19	398.77	79.08	411.91	2251.38	2019.18
Voided	2230.35	260.71	58.51	175.03	983.22	752.71
Digested	2935.84	138.06	20.57	236.88	1268.16	1266.47
Co-efficients or percentages digested	**56.83**	**34.62**	**26.01**	**57.51**	**56.33**	**62.72**

TIMOTHY HAY.

Fodder Fed.—Sheep No. 4.

Weight of fodder received in five days, 5530.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.58	7.21	1.43	7.45	40.71	36.52

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5166.19	398.77	79.08	411.91	2251.31	2019.18

Orts, air dried, weighed 000 grams.

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5166.19	398.77	79.08	411.91	2251.31	2019.18

Feces.

Air dried feces weighed 2275.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.46	10.31	2.23	7.48	42.00	31.48

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2091.19	235.42	50.73	170.11	955.41	716.11

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5166.19	398.77	79.08	411.91	2251.31	2019.18
Voided	2091.19	235.42	50.73	170.11	955.41	716.11
Digested	3075.00	161.35	28.35	241.80	1295.97	1303.07
Co-efficients or percentages digested	**59.52**	**32.94**	**35.85**	**58.70**	**57.56**	**64.53**

TIMOTHY HAY.

Fodder Fed.—Sheep No. 8.

Weight of fodder received in five days, 5530.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.58	7.21	1.43	7.45	40.71	36.52

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5166.19	398.77	79.08	411.91	2251.38	2019.18

Orts, air dried, weighed 65.0 grams.*

Analysis of Orts.

Analysis incomplete.

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
	13.91	1.30	8.82		

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5166.19	398.77	79.08	411.91	2257.38	2019.18
Less orts		13.91	1.30	8.82		
Consumed	5166.19	384.86	77.78	403.09	2251.38	2019.18

Feces.

Air dried feces weighed 2567.5 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.98	9.77	2.06	6.45	43.93	30.80

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2388.21	250.71	51.50	165.62	1127.11	790.71

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5166.19	384.86	77.78	403.09	2251.38	2019.18
Voided	2388.21	250.71	51.50	165.62	1127.11	790.71
Digested	2777.98	134.15	26.28	237.47	1124.27	1228.47
Co-efficients or percentages digested	**53.77**	**34.86**	**33.79**	**58.91**	**49.94**	**60.79**

*The moisture and crude fibre determinations in this sample of orts were omitted, which introduces a slight error into the co-efficients obtained.

Average Digestion Coefficients for Timothy Hay.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 3	56.83	34.62	26.01	57.51	56.33	62.72
Sheep No. 4	59.52	32.94	35.85	58.70	57.56	64.53
Sheep No. 8	53.77	34.86	33.79	58.91	49.94	60.79
Average	56.71	34.14	31.88	58.37	54.61	62.80

The average coefficients obtained are well within the range found by other experimenteıs, with the exception of the coefficient of digestion for the fat or ether extract, which is far below the coefficient given for fat in timothy hay cut before or in bloom, and even lower than the minimum given for fat, 34.6, in timothy hay cut past bloom. The digestion coefficient of crude fibre is lower than the minimum given for timothy hay cut before or in bloom, but above the maximum for timothy cut after bloom. The digestion coefficient for the fat is markedly low. The same fact is observable in the results obtained for the digestion coefficient of fat in corn fodder. The native hay gives us a higher coefficient for the digestibility of the fat or ether extract than is given for blue joint, a meadow grass common in the East; but as already noted, the Eastern blue joint and the Western blue stem are different grasses, and their digestion coefficients may not be the same, in fact, are probably not the same, and my only justification in comparing them is the very general one that they each constitute a meadow hay.

We will have to take up the question of the digestion coefficient of fat in a subsequent paragraph, after we have set forth the results obtained with alfalfa hay.

The timothy hay used was purchased in the Denver market, it had been grown in the mountains, had been cut in early bloom and well cured. It was as good a sample as we could hope to procure either in the market or by growing it on the Station farm.

ALFALFA HAY.

Fodder Fed.—Sheep No. 4.

Weight of fodder received in five days, 5470.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.23	9.63	0.80	13.12	41.05	30.17

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5183.88	526.72	43.76	717.63	2245.23	1650.34

Orts, air dried, weighed 000 grams.

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5183.88	526.72	43.76	717.63	2245.23	1650.34

Feces.

Air dried feces weighed 2340.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.21	10.30	3.06	9.44	44.23	26.76

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2194.63	241.07	71.60	220.80	1034.10	626.11

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5183.88	526.72	43.76	717.63	2245.23	1650.34
Voided	2199.63	241.07	71.60	220.81	1034.10	626.11
Digested	2989.25	285.65	—27.84	496.82	1211.13	1024.23
Co-efficients or percentages digested	**57.66**	**54.23**	**—63.61**	**69.08**	**54.43**	**62.06**

ALFALFA HAY.

Fodder Fed.—Sheep No. 3.

Weight of fodder received in five days, 5470.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.23	9.63	0.80	13.12	41.05	30.17

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5183.88	526.72	43.76	717.63	2245.23	1650.34

Orts, air dried, weighed 000 grams.

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5183.88	526.72	43.76	717.63	2245.23	1650.34

Feces.

Air dried feces weighed 2832.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.26	11.12	3.27	9.27	44.00	26.08

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2654.68	315.03	92.63	262.65	1246.19	738.82

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5183.88	526.72	43.76	717.63	2245.23	1650.30
Voided	2654.68	315.03	92.63	262.65	1246.19	738.82
Digested	2529.20	211.69	—48.87	454.98	999.04	911.52
Co-efficients or percentages digested	**49.56**	**40.19**	**—111.67**	**63.40**	**44.49**	**55.23**

ALFALFA HAY.

Fodder Fed.—Sheep No. 8.

Weight of fodder received in five days, 5470.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.23	9.63	0.80	13.12	41.05	30.17

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
5183.88	526.72	43.76	717.63	2245.23	1650.30

Orts, air dried, weighed 1522.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.44	11.12	0.84	12.44	36.48	32.68

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1423.98	169.24	12.78	189.34	555.23	497.33

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	5183.88	526.72	43.76	717.63	2245.23	1650.34
Less orts	1423.98	169.24	12.78	189.34	555.23	497.39
Consumed	3759.90	357.48	30.98	528.29	1690.00	1152.95

Feces.

Air dried feces weighed 2044.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.99	10.00	2.99	8.38	46.00	26.64

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1921.57	205.40	61.11	171.22	940.22	544.55

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3759.90	357.48	30.98	528.29	1690.00	1152.95
Voided	1921.57	205.40	61.11	171.22	940.22	544.55
Digested	1838.33	152.08	—30.13	357.07	749.78	608.40
Co-efficients or percentages digested	**48.89**	**42.57**	**—97.26**	**67.59**	**44.36**	**52.77**

Average Digestion Coefficients for Alfalfa Hay.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 3	**49.56**	**40.19**	Negative **111.67**	**63.40**	**44.49**	**55.23**
Sheep No. 4	**57.66**	**54.23**	Negative **63.61**	**69.08**	**54.43**	**62.06**
Sheep No. 8	**48.89**	**42.54**	Negative **97.26**	**67.59**	**44.36**	**52.77**
Averages	**52.04**	**45.65**	Negative **90.85**	**66.69**	**47.76**	**56.69**

The maximum, minimum and average coefficients of digesgestion as given by Jordan and Hall are as follows:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Maximum	60.2	40.9	54.0	77.0	49.0	71.8
Minimum	57.0	38.0	48.4	68.8	43.3	64.0
Average	58.9	39.5	51.0	72.0	46.0	69.2

The experiments on which the quoted data were based were made, one by Utah Experiment Station, using two steers; one by the New York Experiment Station, using a cow; one by the Colorado Station, using two steers. Additional experiments which have appeared since the compilation of Jordan and Hall was made are, so far as I have been able to find, the following:

Kansas Station, Bulletin 103.—Steers.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
First cutting, plants in bloom	59.40	63.49	60.00	78.52	46.10	75.31
Second cutting, 50 per cent. of plants in bloom	58.29	56.41	30.39	75.14	50.44	71.99
Third cutting, plants in full bloom	60.03	60.90	51.65	76.70	50.63	75.24

Minnesota Station, Bulletin 80.—Steers.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Alfalfa hay	65.84	51.40	55.88	75.38	57.57	71.86

Ontario Agricultural College and Experimental Farm Report, 1898.—Sheep.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
First cutting	58.6	——	48.8	73.4	39.1	71.8
Second cutting	56.2	——	50.4	72.8	37.7	70.1
Third cutting	51.3	——	44.1	64.4	37.1	64.0

Utah Station.—Bul. 54.—Steers.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
60.16	40.85	50.57	70.30	45.67	71.80

These give for alfalfa hay, first cutting, taking the Minnesota and Utah samples as such, the following:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Average alfalfa hay	61.00	51.58	53.81	74.40	47.11	72.49
Average all cuttings	58.73	56.61	48.97	73.33	45.54	71.41

My average results are lower than the averages of other experimenters, but are within the bounds of probability, with the exception of the fat or ether extract, which in my series is negative, and we assume, tentatively only, that the results are erro-

neous, even though the three sheep give the same result, i. e., a negative one. The natural explanation would be to attribute it to some error, and as the result is common to the three sheep, the error, if any has been made, must be a fundamental one, and would seem to lie in the determination of the fat or ether extract in the hay itself. The hay used was first cutting hay, furnished by the Farm Department, probably cut when the plants were in early to half bloom, as it is our custom to cut the alfalfa when in this condition, though the analysis corresponds to much later cut hay.

The results in the case of the ether extract being so remarkable, the analytical work, though already done in duplicate, was repeated in the case of the hay and the feces of sheep No. 3. The principal weakness in my data lies in the sample of hay, the composition of which shows nothing unusual except a very small amount of fat, ether extract, which is even less than I have heretofore found in the stems alone or in hay made from plants that were in full seed.

This extremely low percentage of fat almost forbids the use of the coefficient obtained for it in this series of experiments.

The crude protein, 13.12 per cent, is a shade low, and the crude fibre, 41.05 per cent, a little too high for prime, first cutting alfalfa hay. But they are so well within the range found for these constituents in alfalfa hay that they cannot justly be made the subject of adverse comment. The fat, however, being less than one-half the amount usually found in good alfalfa hay, is open to the gravest doubts. The feces of the sheep fed on this hay are, on the other hand, quite as rich in ether extract as the feces of other sheep fed with a much better alfalfa hay. The average ether extract found in the feces of this series of experiments, and being the average of fifteen determinations, is 3.10 per cent, while the average percentage of ether extract found in the feces of three other sheep, likewise based upon fifteen determinations, is 3.09 per cent.

It would seem that if the feces of two sets of sheep, to which the same kind of hay had been fed, contained the same amount of ether extract (fat), we ought to find a corresponding agreement in the amounts contained in the hay feed, provided that the digestion processes had acted upon them in the same manner and degree ; but we do not find this to be the case, as will appear more fully in the statement of a subsequent series of experiments. I therefore feel it to be incumbent upon me either to reject this series or to make a somewhat full record of the study made, which I shall do as briefly as possible. It would be easier to do the former and to use only such results as are in harmony with other experiments which are considered as altogether reliable, and the number of which add materially to their conclusiveness.

The hay was passed through a cutter and the sample taken by Professor W. W. Cooke, who was at the time Professor of Agriculture at this institution, and by him delivered to me. The hay was discolored to a degree which might be produced by its being exposed to a heavy dew or a light rain. An analysis of it indicated it to be at least a fair quality of hay, the only thing attracting attention being the very unusually low percentage of ether extract or fat.

Two things were possible in our results: We might have obtained too low results in our analysis of the hay, or those obtained for the fat in the feces might have been too high, and it is conceivable that both determinations might have been wrong, even though the former was made in duplicate and the latter was the average of five closely agreeing determinations. The analysis of both the hay and the feces were repeated without changing the results. It was then thought the alfalfa being very rich in chlorophyll, the coloring matters might have accumulated in the feces and possibly, having been rendered more readily soluble in ether, might account for a part of the discrepency between our results and those of others. The hay and feces of sheep Nos. 3, 4 and 8 were resampled, the samples carefully dried in hydrogen and extracted with petroleum ether, boiling from 35 deg. to 50 deg. Petroleum ether of this boiling point dissolved about 50 per cent as much out of both hay and feces as the anhydrous ether. The petroleum ether Bp. 35 deg.–50 deg., dissolved 1.78, 1.97 and 1.78 per cent from the feces, whereas the anhydrous ether dissolved 3.64, 3.62 and 3.62 per cent. The petroleum extract had a yellowish green color and it was evident that there was some coloring matter present which was freely soluble in this menstruum.

An attempt to separate the fatty acids and in this manner to eliminate the question of coloring matters and bile products, gave unsatisfactory results.

We next tried a higher boiling petroleum, 50 deg.–60 deg. We found this much more difficult to work with than the lower boiling petroleum, and further, that it yielded a much higher percentage of extract, in one instance falling only 0.10 per cent below the ether and in no instance more than 1 per cent less than the ether. After extracting five samples with petroleum Bp. 50 deg.–60 deg., we abandoned it and had recourse to alternate extraction with petroleum Bp. 35 deg.–50 deg. and anhydrous ether, also treating same samples in reverse order. As a result of this treatment we found that samples treated with ether yield but little, 0.07 per cent average of three trials, to petroleum Bp. 35 deg.–50 deg., while those treated with petroleum Bp. 35 deg.–50 deg. yield 0.90 per cent to the ether. At first I supposed that this difference was due to chlorophyll soluble in ether, but insol-

uble in the petroleum; subsequent attempts to separate the coloring matters from these extracts, though very unsatisfactory in themselves, indicate that this assumption was not wholly justified. The coefficient of digestion for the fat, petroleum extract, was negative, as in the case of the ether extract—showing over twice as much fat in the feces as was ingested with the hay; the negative coefficient for the ether extract being 111.67 and for the petroleum 110.8.

The next thing suggesting itself was that the excess of substances extracted from the feces by the ether might be due to biliary products, and we sought for cholesterine and bile pigments. We did not obtain satisfactory crystallizations of cholesterine, but we did obtain a good Petenkofer reaction. This is hardly to be wondered at, as this substance occurs so generally distributed within the body. We obtained fairly good reactions for bile pigments, and were it not for the presence of other substances which might have produced the reactions observed, one would be justified in asserting that they were present. As the matter stands, however, I am very doubtful about the actual presence of bile pigments, and I am very fully convinced that this class of products do not furnish the explanation for the excessive amount of extract in the feces. By excessive is here meant relative to the amount in the hay feed.

We attempted to determine the chlorophyll in these extracts; the results were, as was to be foreseen, unsatisfactory, but indicated that from 30 to 35 per cent of the extract consists of chlorophyll and related substances. The petroleum extract was not colorless, but contained a considerable quantity of coloring matter. This coloring matter was also soluble in ether, for when the sample was first extracted with ether, and then with petroleum, the latter remained colorless. The large amount of coloring matter in alfalfa gave us trouble in other operations; for instance, we found it necessary to use lead and copper salts jointly in obtaining a colorless solution from an alcoholic extract of alfalfa hay.

The question of the coloring matters was not prosecuted further and was considered to this extent only because of their direct disturbing influence upon our fat determinations and indirectly upon some of our work due to the color imparted to the solutions, making it difficult to observe the reactions or to determine when the end had been reached.

In all of this we have been unable to find any explanation of the fact that this series of experiments gives us no digestion coefficient for the ether extract in alfalfa hay. I have canvassed all of the analytical difficulties which have occurred to me as possibly being capable of furnishing even a suggestion of an explanation, the analysis of the hay and also those of the feces have been repeated several times by different operators and with great

care. The results are so constant that they preclude any mistake in the analytical work. To convey an idea of the care with which my assistants worked and the concordant results obtained, I may be permitted to give some of them: Ether extract in alfalfa hay, 0.783, 0.835, 0.785, 0.812 and 0.750, after resampling and prolonged drying in hydrogen. Ether extract in the only sample of orts left by the sheep was 0.827, 0.850. The results obtained in the analysis of the feces were equally satisfactory.

The only suggestion remaining is that the hay used in this experiment had suffered some change which affect the solubility of the "ether extract" in this remarkable manner, i. e., reducing it to about one-half the amount to be expected in good alfalfa hay, this hay showing 0.80 per cent, while the next sample experimented with contained 1.62 per cent and was likewise first cutting but in much better condition. The orts show the same relation; the orts in this series show an average of 0.83 per cent ether extract, in the next one to be given 1.22 per cent. Of the three sheep used only one left any portion of its fodder, and I am inclined to consider it an accident that the fat in the hay and orts in this one sample are so nearly the same. The feces, on the other hand, do not show this difference, but are very similar in the percentage of ether extract yielded.

As already stated, the feces from this hay containing only 0.80 per cent ether extract yielded as the average of fifteen determinations made on the feces of three sheep 3.10 per cent, while the feces from another alfalfa hay yielded as the average of the same number of determinations made on the feces of three other sheep 3.09 per cent. One thing is evident, i. e., that however changed the hay may have been, this change did not affect the amount of ether extract appearing in the feces.

There are no facts that I know of to justify us in assuming that oxidation would diminish the solubility of the fats in alfalfa hay, even if slightly damaged by rain or dew, as this may have been. Beyond this I cannot conceive by what cause the fat in this hay could have been so reduced, and I am still less able to apprehend what changes could have taken place within the animal to restore an apparently *normal* amount of ether extract to the feces.

It is almost certain that the ether extract consists of soluble fecal matter, the amount of which is not dependent upon the amount of ether extract in the hay, and the coefficient obtained is of but little value.

It is generally accepted as a fact that the determination of the coefficient of digestion of fat, especially when only small amounts are fed, is at best unsatisfactory. This is applicable in the case of hays and fodders in which the amount of fat or ether

extract is small. In the case here presented the largest amount of ether extract consumed in the five days during which the feces were collected was 43.76 grams, a little less than an ounce and a half. This is a small quantity, but concerning the result there is no room for questions, it is not doubtful, for we find in the feces 92.63 grams of fat or ether extract—more than twice the amount consumed, and we find almost exactly the same ratio if we take the petroleum extract, i. e., 23.52 grams consumed and 48.99 grams voided in the feces. All uncertainty in regard to the coefficient disappears in this markedly negative result. While I am unable to give any explanation, satisfactory or otherwise, for this anomalous result, except as already suggested, I cannot, in fairness, do otherwise than publish the results obtained.

I see but one question which can still be raised, i. e., the character of the sample itself. The experience of Professor Cooke as a chemist and his own interest in the experiment ought to be a sufficient guaranty of its fairness. The fact that the one sample of orts obtained in the experiment gives the same amount of ether extract that the sample of hay gave is remarkable, for sheep, when they have the opportunity, eat the leaves of alfalfa in preference to the stems, and the fact that this hay had been chopped would in no way preclude the animals leaving the stems in preference to a mixture of leaves and stems. The analysis, as already intimated, suggests a sample of hay which had been cut when passed full bloom, but by what process the ether extract in the feces has been rendered so large is not apparent.

SECOND SERIES.

It was my intention to extend the work with the preceding hays and fodders to include a study of the alcoholic and aqueous extracts together with several other points which appear to me interesting and possibly of considerable value. The doubts which gathered about the alfalfa hay and the anamalous results obtained decided me to take up another series of experiments. I accordingly obtained other sheep and repeated the work *de novo*. I was the more willing to do this, as it would increase the number of experiments made and the number of animals experimented with, both of which are desirable factors in this kind of work, besides there is a scarcity of experiments to determine the coefficients of some of the fodders with which I wished to experiment. Some of the conditions, too, under which the experiments were conducted were made more favorable. The comfort of the animal was better provided for and the spring season was chosen instead of the summer.

It further seemed advisable to extend the experiments to include sorghum fodder raised without irrigation and one of our na-

tive salt bushes, *Atriplex argentea*, because they are of importance to the eastern section of the state, which is largely devoted to grazing. The cattlemen find it desirable to have some fodder to feed during severe storms, as by doing so they avoid during the late winter and spring the loss of cattle, which are already somewhat reduced by the scanty supply of grass and the exposures of the season. Owing to the climatic conditions prevailing in this section it would be a boon if some of the native plants could be used for fodder when dried. As the salt bush mentioned, *Atriplex argentea*, has been used for this purpose, I included it in our experiment. In regard to the sorghum fodder, two things are to be considered; first, it is necessary to grow it without irrigation and with but little rainfall; the average rainfall of Cheyenne Wells is 15.90 inches; second, the plants will not grow rankly and the fodder would not be used until the latter part of winter or some time during the spring, by which time it is claimed that sorghum fodder will have deteriorated very materially. But even under these conditions one would judge sorghum fodder to be preferable to hay made from the Russian thistle or some of the salt bushes.

The Sub-station at Cheyenne Wells experimented with the growing sorghum for this purpose. The cultural problems lie entirely beyond my province. The sample of sorghum fodder used was grown by this Sub-station, cut when only a few of the plants were advanced enough to mature seed, shocked and preserved in shock until the following spring. The sample was leafy and of an excellent color, and whatever the changes this fodder may have suffered due to its having stood in shock, exposed to the weather of an eastern Colorado winter, it is still representative of the very best sorghum fodder that the people of this section can hope to obtain.

The second series of experiments include the following: Alfalfa hay, native hay, timothy hay, corn fodder, sorghum fodder and salt bush hay.

The sheep used in these experiments were wethers about one year old, so-called Mexican lambs, and represented the stock fed by feeders in this valley. The sheep were rather under-sized but healthy and hardy. They were gentle and their stalls were light and airy, so arranged that we could close them nights and during severe weather. The water given them to drink was heated to from 14 deg. to 20 deg. C., and in cold weather to from 35 deg. to 40 deg., usually to about 30 deg. During this series of experiments the sheep received a small allowance of salt, except with the salt bush hay. The weights of the sheep were taken on the morning of the day the experiments began, before feeding, and on the morning of the day they were turned out of the stalls twelve hours after the last feed.

ALFALFA HAY.

Fodder Fed.—Sheep No. 4.

Weight of fodder received in five days, 4450.5 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.75	11.77	1.62	15.03	30.28	35.55

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4106.00	533.23	72.01	668.12	1346.10	1580.27

Orts, air dried, weighed 320.7 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.32	20.74	1.22	14.93	32.44	25.35

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
323.60	66.51	3.91	47.88	104.03	81.29

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4106.00	523.23	72.01	668.12	1346.10	1580.27
Less orts	323.60	66.51	3.91	47.88	104.03	81.29
Consumed	3782.40	456.72	68.18	620.24	1242.07	1498.98

Feces.

Air dried feces weighed 1485.20 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.68	13.37	3.09	10.99	39.95	25.92

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1386.00	198.51	45.89	163.25	593.34	384.92

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3782.40	456.72	68.18	620.24	1242.07	1498.98
Voided	1386.00	198.51	45.89	163.25	593.34	384.92
Digested	2396.40	258.21	22.29	456.99	648.76	1114.06
Co-efficients or percentages digested	**63.64**	**56.54**	**32.61**	**73.68**	**52.23**	**74.32**

Weight of sheep at beginning of experiment 46.0 pounds.
Weight of sheep at end of experiment 49.0 pounds.

ALFALFA HAY.

Fodder Fed.—Sheep No. 5.

Weight of fodder received in five days, 4450.5 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.75	11.77	1.62	15.03	30.28	35.55

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4106.00	523.23	72.01	668.12	1346.1	1580.27

Orts, air dried, weighed 436.7 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.52	22.10	1.32	19.12	24.44	27.50

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
412.60	96.51	5.76	83.44	106.73	120.01

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4106.00	523.23	72.01	668.12	1346.10	1580.27
Less orts	412.60	96.51	5.76	83.44	106.73	120.01
Consumed	3693.40	426.72	66.25	564.68	1239.37	1460.26

Feces.

Air dried feces weighed 1426.7 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.73	11.77	3.06	10.46	41.72	26.26

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1130.69	167.94	43.65	149.22	595.25	374.61

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3693.40	426.72	66.25	564.68	1239.37	1460.26
Voided	1130.69	167.94	43.65	149.22	595.25	374.61
Digested	2562.71	258.78	22.60	415.48	644.12	1085.65
Co-efficients or percentages digested	**69.39**	**60.64**	**34.11**	**75.58**	**51.97**	**74.35**

Weight of sheep at beginning of experiment 46.0 pounds.
Weight of sheep at end of experiment 49.0 pounds.

ALFALFA HAY.

Fodder Fed.—Sheep No. 6.

Weight of fodder received in five days, 4450.5 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
7.75	11.77	1.62	15.03	30.28	35.55

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4106.00	523.23	72.01	668.12	1346.10	1580.27

Orts, air dried, weighed 229.3 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.45	22.02	1.12	16.78	30.73	23.90

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
216.81	50.49	2.57	38.48	70.46	43.53

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4106.00	523.23	72.01	668.12	1346.10	1580.27
Less orts	216.81	50.49	2.57	38.48	70.46	43.53
Consumed	3889.19	472.74	69.52	629.64	1275.64	1536.74

Feces.

Air dried feces weighed 1718.6 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.82	12.15	3.12	10.86	40.34	26.83

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1601.36	208.83	53.62	186.21	693.31	461.12

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3889.19	472.74	69.52	629.64	1275.64	1536.74
Voided	1601.36	208.83	53.62	186.21	693.31	461.12
Digested	2287.83	263.91	15.91	443.42	582.33	1075.62
Co-efficients or percentages digested	**58.83**	**55.83**	**22.85**	**70.36**	**45.65**	**69.99**

Weight of sheep at beginning of experiment 42.0 pounds.
Weight of sheep at end of experiment 45.0 pounds.

The Average Co-efficients.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 4	**63.64**	**56.54**	**32.61**	**73.68**	**52.23**	**74.32**
Sheep No. 5	**63.69**	**60.64**	**34.11**	**73.58**	**51.97**	**74.35**
Sheep No. 6	**58.83**	**55.83**	**22.85**	**70.36**	**45.65**	**69.99**
Average	**63.95**	**57.67**	**29.86**	**72.54**	**49.93**	**72.89**

If we do not include the coefficient 22.85 found for the fat in the experiment with sheep No. 6, we would still have only 33.34 as the average for sheep Nos. 4 and 5, which is still very much lower than has been found by any other experimenter for any cutting of alfalfa hay. A very little of the hay used in these experiments was slightly mouldy, the rest of the hay was in prime condition and the sample was fair. The highest average coefficient which we find for the fat or ether extract is 33.34, and that actually found for the three sheep is 29.86, while the highest individual coefficient is 34.11. All that has been said concerning the care taken to eliminate analytical errors in the first series of experiments with alfalfa, applies to this, and we believe that we have succeeded in eliminating them.

CORN FODDER.

Fodder Fed.—Sheep No. 1.

Weight of fodder received in five days, 3896.2 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
8.21	9.53	1.55	4.62	29.85	46.24

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
3576.37	371.22	60.36	179.91	1162.12	1802.14

Orts, air dried, weighed 818.6 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.79	8.49	1.28	2.49	35.02	45.93

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
763.02	69.49	10.47	20.38	286.61	375.91

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	3576.37	371.22	60.36	179.91	1162.12	1802.14
Less orts	763.02	69.49	10.47	20.38	286.61	375.91
Consumed	2813.35	301.73	49.89	159.53	875.51	1426.23

Feces.

Air dried feces weighed 1400.3 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.73	12.63	1.12	7.16	30.16	42.20

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1306.06	176.82	19.74	100.22	422.33	590.94

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2813.35	301.73	49.89	159.53	875.51	1426.23
Voided	1306.06	176.82	19.74	100.22	422.33	590.94
Digested	1507.29	124.91	30.15	59.31	453.18	835.29
Co-efficients or percentages digested	**53.58**	**41.39**	**60.43**	**37.18**	**51.76**	**57.16**

Weight of sheep at beginning of experiment 47.0 pounds.

Weight of sheep at end of experiment 49.0 pounds.

CORN FODDER.

Fodder Fed.—Sheep No. 2.

Weight of fodder received in five days, 3896.2 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
8.21	9.53	1.55	4.62	29.85	46.24

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
3576.37	371.22	60.36	179.91	1162.12	1802.14

Orts, air dried, weighed 995.6 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.72	7.66	1.30	2.59	35.01	46.72

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
928.7	76.26	12.94	25.78	348.52	465.12

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	3576.37	371.22	60.63	179.91	1162.12	1802.14
Less orts	928.70	76.26	12.94	25.78	348.52	465.12
Consumed	2647.67	294.96	47.42	154.13	813.60	1337.02

Feces.

Air dried feces weighed 1230.4 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.67	13.26	1.19	7.83	29.20	42.00

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1148.34	163.12	14.64	96.34	359.21	516.71

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2647.67	294.96	47.42	154.13	813.60	1337.02
Voided	1148.34	163.12	14.64	96.34	359.21	516.71
Digested	1499.33	131.84	332.77	57.79	454.39	820.31
Co-efficients or percentages digested	**56.63**	**44.70**	**69.11**	**37.49**	**55.85**	**61.35**

Weight of sheep at beginning of the experiment 46.0 pounds.
Weight of sheep at end of experiment 47.0 pounds.

CORN FODDER.

Fodder Fed.—Sheep No. 3.

Weight of fodder received in five days, 3896.2 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
8.21	9.53	1.55	4.62	29.85	46.24

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
3576.37	371.22	60.36	179.91	1162.12	1802.14

Orts, air dried, weighed 800.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.47	7.22	1.26	2.63	37.19	45.23

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
748.24	57.76	10.08	21.04	297.55	362.83

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	3576.37	371.22	60.36	179.91	1162.12	1802.14
Less orts	748.24	57.76	10.08	21.04	297.55	362.83
Consumed	2828.13	313.46	50.28	158.87	864.57	1439.31

Feces.

Air dried feces weighed 1220.2 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.76	14.17	1.29	7.90	26.56	43.32

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1137.72	172.94	15.74	95.73	324.01	528.51

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2828.13	313.46	50.28	158.87	864.57	1439.31
Voided	1137.73	172.94	15.74	95.73	324.01	528.51
Digested	1690.41	140.52	34.54	63.14	540.56	910.80
Co-efficients or percentages digested	**59.77**	**44.83**	**68.69**	**33.45**	**62.52**	**63.28**

Weight of sheep at beginning of experiment 48.5 pounds
Weight of sheep at end of experiment 49.0 pounds.

Average Digestion Co-efficients of Corn Fodder.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 1	**53.58**	**41.39**	**60.43**	**37.18**	**51.76**	**57.16**
Sheep No. 2	**56.63**	**44.70**	**69.11**	**37.49**	**55.85**	**61.35**
Sheep No. 3	**59.77**	**44.83**	**68.69**	**33.45**	**62.52**	**63.28**
Average	**56.66**	**43.64**	**66.08**	**36.04**	**56.71**	**60.60**

The fodder used in the preceding experiments was obtained from the Farm Department. It was cut August 20, stood in shock until November 22, when it was hauled in and stacked, where it remained till March 10. The fodder was bright, prime fodder. The corn was a variety of dent, and was mature enough to have a few ears so far developed that the corn hardened up while in shock. All of the ears and nubbins were husked out. The corn had been seeded thinly in drills. The ratio of the leaves to the stems was 2-1. The fodder was cut fine, from one-fourth to one-half inch long. The orts consisted wholly of stalks, as the sheep ate all the leaves. We did not succeed in inducing the sheep to eat all the stems, even when they had been ground in a drug mill and moistened.

Jordan and Hall give as maximum, minimum and average digestion coefficients for dent and flint corn fodder (mature):

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Maximum	72.7	52.9	82.0	67.6	79.8	81.2
Minimum	59.8	6.6	64.7	37.9	42.8	63.4
Average	68.2	30.6	73.9	56.1	55.8	72.2

The same authors give the maximum, minimum and average coefficients for dent and flint cornfodder, immature, as:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Maximum	69.8	57.4	79.5	70.5	74.6	74.0
Minimum	52.3	17.7	57.3	24.1	46.1	59.2
Average	63.9	37.2	72.2	51.7	66.0	66.2

The coefficients obtained for our three individual sheep agree very well indeed, but our averages are quite different from those given in the compilation cited. Neglecting the ash and considering the other results, we have the following exhibit of facts relative to the digestibility of corn fodder, with which many experi-

ments have been made, the most of them by Eastern experimenters, and naturally under Eastern conditions.

My first series of experiments gave the following results—corn fodder inmature:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 1	56.43	47.08	48.04	47.46	64.07	54.90
Sheep No. 2	60.28	42.29	45.40	46.07	70.24	60.25
Sheep No. 3	58.98	39.06	44.28	48.62	69.30	57.66
Average	**58.56**	**42.84**	**45.91**	**47.38**	**67.87**	**57.60**

Second series. Corn fodder, grown thinly in drills and mature enough to ripen a few ears:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 1	53.58	41.39	60.43	37.18	51.76	57.16
Sheep No. 2	56.63	44.70	69.11	37.49	55.85	61.35
Sheep No. 3	59.77	44.83	68.69	33.45	62.52	63.28
Average	**56.66**	**43.64**	**66.08**	**36.04**	**56.71**	**60.60**

The coefficients obtained for the individual sheep in the respective series agree as well as could be expected, and while the two series vary greatly, as it is proper that they should, all of the conditions under which the experiments were made being different in every respect. Still the results have a common feature when compared with the results recorded by all other American experimenters, i. e., they are uniformly low. This is, perhaps, most fairly shown by taking the averages, but, as will be noticed upon mere inspection, I might take the minima given by others and my result would still be comparatively low, but, as suggested, the averages may be fairer.

The averages found in Jordan and Hall, "The Digestibility of American Feeding Stuffs," are for dent and flint corn fodder:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Immature	63.9	37.20	72.2	51.7	66.0	66.2
Mature	68.2	30.60	73.9	56.1	55.8	72.2
My first series	58.6	42.84	45.9	47.4	67.9	57.6
My second series	56.7	43.64	66.1	36.0	56.7	60.6

In only one instance does the average found for any of the constitnents given exceed the average given by Jordan and Hall, i. e., the coefficient found for crude fibre. With this exception my coefficients are all low. I will take up this point later, but will remark that in spite of the low coefficients obtained, the animals were gaining flesh, as the three made an aggregate gain of three and a half pounds in the five days. The ration fed was not, in my opinion, such as to permit any unusual portion of it to pass the animal without having been fully acted on by the digestion processes. The amount of dry matter consumed was 2.7 per cent. of the animal's weight, a ratio which is by no means excessive.

TIMOTHY HAY.

Fodder Fed Sheep No. 1.

Weight of fodder received in five days, 4440. grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.49	9.37	2.99	5.62	31.54	43.99

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4151.88	416.03	132.72	249.54	1400.26	1923.64

Orts, air dried, weighed 1269.6 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
4.99	6.97	1.48	5.83	33.20	47.53

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1206.25	88.49	18.79	74.01	421.52	603.42

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4151.88	416.03	132.72	249.54	1400.26	1923.64
Less orts	1206.25	88.49	18.79	74.01	421.52	603.42
Consumed	2945.63	327.54	113.93	175.53	978.74	1320.22

Feces.

Air dried feces weighed 1549.9 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.79	7.84	2.28	5.92	37.26	39.91

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1444.67	121.59	35.33	91.75	577.41	618.52

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2945.63	327.54	113.93	175.53	978.74	1320.22
Voided	1444.67	121.59	35.33	91.75	577.41	618.52
Digested	1500.96	205.95	78.60	83.78	401.33	702.70
Co-efficients or percentages digested	**50.96**	**62.88**	**68.99**	**47.73**	**41.00**	**53.23**

Weight of sheep at beginning of experiment 47.5 pounds.
Weight of sheep at end of experiment 48.0 pounds.
Daily consumption of dry matter equalled 2.7 per cent of the animals weight.

TIMOTHY HAY.

Fodder Fed Sheep No. 2.

Weight of fodder received in five days, 4440.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.49	9.37	2.99	5.62	31.54	43.99

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4151.88	416.03	132.72	249.54	1400.26	1923.64

Orts, air dried, weighed 1329.4 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.78	6.71	2.14	7.93	37.44	40.00

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1232.53	89.20	28.44	105.45	497.74	531.72

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4151.88	416.03	132.72	249.54	1400.26	1923.64
Less orts	1232.53	89.20	28.44	105.45	497.74	531.72
Consumed	2919.35	326.83	104.28	144.09	902.52	1391.92

Feces.

Air dried feces weighed 1549.7 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.35	6.72	2.06	5.48	39.75	39.64

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1451.30	104.13	31.92	84.92	616.02	614.21

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2919.35	326.83	104.28	144.09	902.52	1391.92
Voided	1451.30	104.13	31.92	84.92	616.02	614.21
Digested	1468.05	222.70	72.36	59.17	286.50	777.71
Co-efficients or percentages digested	**50.28**	**68.14**	**69.39**	**41.06**	**31.94**	**55.87**

Weight of sheep at beginning of experiment 48.0 pounds.
Weight of sheep at end of experiment 47.5 pounds.
Daily consumption of dry matter equalled 2.7 per cent of the animals weight.

TIMOTHY HAY.

Fodder Fed Sheep No. 3.

Weight of fodder received in five days, 4440.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.49	9.37	2.99	5.62	31.54	43.99

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4151.88	416.03	132.72	249.54	1400.26	1923.64

Orts, air dried, weighed 1893.7 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.26	6.66	1.62	6.11	38.13	42.22

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1794.10	126.15	30.67	115.72	722.01	799.55

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4151.88	416.03	132.72	249.54	1400.26	1923.64
Less orts	1794.10	126.15	30.67	115.72	722.01	799.55
Consumed	2357.78	289.88	102.02	123.82	678.25	1124.09

Feces.

Air dried feces weighed 1208.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.00	8.19	2.57	6.02	36.34	41.08

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1135.52	98.93	31.04	72.72	438.91	496.22

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	2357.78	289.88	102.05	123.82	678.25	1124.09
Voided	1135.52	98.93	31.04	72.72	438.91	496.22
Digested	1222.26	190.95	71.01	51.10	239.34	627.87
Co-efficients or percentages digested	**51.84**	**65.87**	**69.58**	**41.27**	**35.29**	**55.86**

Weight of sheep at beginning of experiment 47.0 pounds.
Weight of sheep at end of experiment 46.0 pounds.
Daily consumption of dry matter equalled 2.2 per cent of animals weight.

Average Digestion Co-efficients for Timothy Hay.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 1	**50.96**	**62.88**	**68.99**	**47.73**	**41.00**	**53.23**
Sheep No. 2	**50.28**	**68.14**	**69.39**	**41.06**	**31.94**	**55.87**
Sheep No. 3	**51.84**	**65.87**	**69.58**	**41.27**	**35.29**	**55.86**
Average	**51.03**	**65.63**	**69.32**	**43.35**	**36.08**	**54.99**

The hay fed was not the same as in the former experiment. The sheep were younger and of a different breed, and the conditions of air, sunlight and general attention to the comfort of the animal were more favorable than in the former experiment. All of these facts should be taken into consideration in comparing the results. As both samples of hay were obtained in the Denver market, I cannot be more than morally certain that they were of about the same age, bnt I really entertain no doubt on this point. If we may judge by the amount of orts left, the hay used in the first experiment was more palatable to the sheep than that used in the second. The total amount of orts left by the three sheep in the first experiment was 60 grams, while they aggregated 4493.0 grams in the second.

The individual taste of one of the sheep was very marked in the second series, as it seemingly ate none of the timothy heads, all of which seemed pretty mature.

I will restate the results obtained in the first experiment that the differences may be the more easily observed:

The Digestion Co-efficients of Timothy Hay, First Series.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 3	56.83	34.62	26.01	57.51	56.33	62.72
Sheep No. 4	59.52	32.94	35.85	58.70	57.56	64.53
Sheep No. 8	53.77	34.86	33.79	58.91	49.94	60.79
Average	56.71	34.14	31.88	58.37	54.61	62.80

Jordan and Hall give the digestion coefficients for timothy hay before or in bloom as follows:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Maximum	65.7	48.2	60.8	60.4	62.1	71.8
Minimum	55.9	41.8	51.5	51.1	56.6	57.4
Average	60.7	44.2	58.4	56.8	58.8	64.3
Timothy hay past bloom.						
Average	53.4	30.3	51.9	45.1	47.1	60.4

The coefficient found for the fat or ether extract in the second series seems to be an exception, being much higher than the maximum given by Jordan and Hall for this constituent of the hays, but the coefficients found for the three sheep are in much closer agreement than we usually find to be the case in this work. With this exception we find in both series a very marked tendency toward lower coefficients than other experimenters have found—a result which was specifically mentioned in connection with the coefficients found for corn fodder.

NATIVE HAY.

Fodder Fed Sheep No. 4.

Weight of fodder received in five days, 4394.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.13	10.64	3.13	6.98	31.38	42.74

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4168.56	467.54	137.53	306.71	1388.12	1878.23

Orts, air dried, weighed 839.5 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.22	9.84	3.05	6.09	31.34	44.46

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
795.68	82.60	25.60	51.12	263.01	373.23

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4168.56	467.54	137.53	306.71	1388.12	1878.23
Less orts	795.68	82.60	25.60	51.12	263.01	373.23
Consumed	3372.88	384.94	111.93	255.59	1125.11	1505.00

Feces.

Air dried feces weighed 1643.8 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.03	12.92	5.12	5.78	27.99	42.16

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1544.68	212.31	84.16	95.01	406.19	693.04

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3372.88	384.94	111.93	255.59	1125.11	1505.00
Voided	1544.68	212.31	84.16	95.01	406.19	693.04
Digested	1828.20	172.61	27.74	160.58	664.92	812.96
Co-efficients or percentages digested	**54.20**	**44.88**	**22.10**	**62.83**	**59.09**	**54.02**

Weight of sheep at beginning of experiment 50.0 pounds.
Weight of sheep at end of experiment 50.5 pounds.
Daily consumption of dry matter equalled 3.0 per cent of the animals weight.

NATIVE HAY.

Fodder Fed Sheep No. 5.

Weight of fodder received in five days, 4394.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.13	10.64	3.13	6.98	31.38	42.74

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4168.56	467.54	137.53	306.71	1388.12	1878.23

Orts, air dried, weighed 954.5 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.06	7.69	2.99	5.41	33.32	45.53

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
906.21	73.40	28.53	51.63	318.01	434.51

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4168.56	467.54	137.53	306.71	1388.12	1878.23
Less orts	906.21	73.40	28.53	51.63	318.01	434.51
Consumed	3262.35	394.14	109.00	255.08	1070.11	1443.72

Feces.

Air dried feces weighed 1766.4 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.91	13.42	5.17	5.48	28.12	41.90

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1642.09	237.02	91.32	96.79	496.78	740.14

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3262.35	394.14	109.00	255.08	1070.11	1443.72
Voided	1642.09	237.02	91.32	96.79	496.78	740.14
Digested	1620.26	157.12	17.68	158.29	573.33	703.58
Co-efficients or percentages digested	**46.60**	**39.76**	**16.22**	**62.06**	**53.58**	**48.74**

Weight of sheep at begining of the experiment 50.0 pounds.
Weight of sheep at the end of the experiment 50.5 pounds.
Daily consumption of dry matter equalled 2.9 per cent of the animals weight.

NATIVE HAY.

Fodder Fed Sheep No. 6.

Weight of fodder received in five days, 4394.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.13	10.64	3.13	6.98	31.38	42.74

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4168.56	467.54	137.53	306.71	1388.12	1878.23

Orts, air dried, weighed 803.3 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.23	9.93	2.60	6.09	31.40	44.65

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
761.29	79.76	20.88	48.93	252.22	358.62

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4168.56	467.57	137.53	306.71	1388.12	1878.23
Less orts	761.29	79.76	20.88	48.93	252.22	358.62
Consumed	3407.27	387.78	116.65	257.78	1135.90	1519.61

Feces.

Air dried feces weighed 1783.0 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.96	12.41	5.02	5.48	29.29	41.84

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1676.78	221.21	89.50	97.71	522.26	746.01

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3407.27	387.78	116.73	257.78	1135.90	1519.61
Voided	1676.78	221.21	89.50	97.71	522.26	746.01
Digested	1730.49	166.57	27.23	160.07	613.64	773.60
Co-efficients or percentages digested	**50.79**	**42.95**	**23.33**	**62.09**	**54.02**	**51.09**

Weight of sheep at the beginning of the experiment 45.0 pounds.
Weight of sheep at the end of the experiment 47.5 pounds.
Daily consumption of dry matter equalled 3.3 per cent of the animals weight.

The Average Digestion Co-efficients for Native Hay.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 4	**54.20**	**44.84**	**22.10**	**62.83**	**59.09**	**54.02**
Sheep No. 5	**46.60**	**39.76**	**16.22**	**62.06**	**53.58**	**48.78**
Sheep No. 6	**50.79**	**42.95**	**23.33**	**62.09**	**54.02**	**51.09**
Average	**50.53**	**42.52**	**20.55**	**62.33**	**55.56**	**51.30**

I have stated in connection with the first series of experiments that I know of no data really applicable to this, which we designate as native hay.

The coefficients found for these two hays with which I have experimented agree fairly well, with the exception of those found for the ether extract, which are very far apart. The hays were composed of different grasses and were grown in localities twenty-two miles apart. The average coefficients found in the first series of experiments were as follows:

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
59.78	43.32	47.09	60.90	61.36	62.01

This hay seems to have been a decidedly more digestible one than that used in the second series. The grass constituting the greater part of that used in the second experiment was Colorado blue stem, *Agropyron tenerum.*

SORGHUM FODDER.

Fodder Fed Sheep No. 1.

Weight of fodder received in five days, 4441.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.75	8.17	1.55	5.80	23.26	55.47

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4185.68	371.21	68.83	258.51	1055.45	2019.45

Orts, air dried, weighed 482.3 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.37	10.19	1.29	4.97	28.43	48.75

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
457.95	38.95	4.93	19.00	108.61	186.31

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4185.68	371.21	68.83	258.51	1055.45	2019.45
Less orts	457.95	38.95	4.93	19.00	108.61	186.31
Consumed	3727.73	332.26	63.70	239.51	946.84	1833.14

Feces.

Air dried feces weighed 1698.8 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.80	11.46	1.28	8.48	28.16	43.82

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1583.24	194.61	21.74	144.02	478.34	744.47

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3727.73	332.26	63.70	239.51	946.84	1833.14
Voided	1583.24	194.61	21.74	144.02	478.34	744.47
Digested	2144.49	137.65	41.96	95.49	468.50	1088.67
Co-efficients or percentages digested	**57.53**	**41.43**	**65.87**	**39.87**	**49.38**	**59.39**

Weight of the sheep at the beginning of the experiment 53.5 pounds.
Weight of the sheep at the end of the experiment 50.5 pounds.
Daily consumption of dry mattr equalled 3.1 per cent of the animals weight.

SORGHUM FODDER.

Fodder Fed Sheep No. 2.

Weight of fodder received in five days, 4441.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.75	8.17	1.55	5.80	23.26	55.47

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4185.68	371.21	68.83	258.51	1055.45	2019.45

Orts, air dried, weighed 890.8 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
8.09	8.35	1.25	4.55	25.14	52.62

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
818.74	74.38	11.13	40.53	223.92	468.73

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4185.68	371.21	68.83	258.51	1055.45	2019.45
Less orts	818.74	74.38	11.13	40.53	223.92	468.73
Consumed	3366.94	296.83	57.70	217.98	732.53	1550.72

Feces.

Air dried feces weighed 1502.1 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.42	11.15	1.47	8.38	28.18	44.40

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1405.65	167.41	22.08	125.81	423.35	666.91

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3366.94	296.83	57.70	217.98	732.53	1550.72
Voided	1405.65	167.41	22.08	125.81	423.35	666.91
Digested	1961.29	129.42	35.62	92.17	309.18	883.81
Co-efficients or percentages digested	**58.22**	**43.60**	**61.73**	**42.28**	**42.21**	**56.99**

Weight of the sheep at the beginning of the experiment 49.5 pounds.
Weight of the sheep at the end of the experimnt 47.0 pounds.
Daily consumption of dry matter equalled 3.0 per cent of the animal's weight.

SORGHUM FODDER.

Fodder Fed Sheep No. 3.

Weight of fodder received in five days, 4441.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract
5.75	8.17	1.55	5.80	23.26	55.47

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
4185.68	371.21	68.83	258.51	1055.45	2019.45

Orts, air dried, weighed 375.6 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
8.26	10.54	1.27	4.70	24.76	50.47

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
344.58	39.58	4.77	17.65	92.99	185.22

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	4185.68	371.21	68.83	258.51	1055.45	2019.45
Less orts	344.58	39.58	4.77	17.65	92.99	185.22
Consumed	3841.10	331.63	64.06	240.86	962.46	1834.23

Feces.

Air dried feces weighed 1648.4 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.66	11.57	1.44	8.69	28.77	41.07

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
1550.61	169.81	21.14	127.61	422.42	608.93

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	3841.10	331.63	64.06	240.86	962.46	1834.23
Voided	1550.61	169.81	21.14	127.61	422.42	608.93
Digested	2290.49	161.82	42.92	113.25	540.04	1225.30
Co-efficients or percentages digested	**59.63**	**48.80**	**67.00**	**47.02**	**56.11**	**66.80**

Weight of the sheep at the beginning of the experiment 56.0 pounds.
Weight of the sheep at the end of the experimnt 53.0 pounds.
Daily consumption of dry mattr equalled 3.0 per cent of the animal's weight.

Average Co-efficients for Sorghum Fodder.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 1	**57.53**	**41.43**	**65.87**	**39.87**	**49.38**	**59.39**
Sheep No. 2	**58.22**	**43.60**	**61.73**	**42.28**	**42.21**	**56.99**
Sheep No. 3	**59.63**	**48.80**	**67.00**	**47.02**	**56.11**	**66.80**
Average	**58.46**	**44.61**	**64.87**	**43.06**	**49.23**	**61.06**

There are but few recorded experiments upon the digestibility of sorghum fodder. The following is quoted by Jordan and Hall from the publications of the North Carolina Station—two experiments with sorghum fodder (pulled from Black African and Collier canes):

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
First, with goat	59.89	17.64	47.14	59.46	64.88	62.51
Second, with cow	66.29	41.31	46.25	62.20	75.88	66.55

There is a record of two experiments by the Texas Station, but the fodder was cut in dough state and fed green. This fact would make but little difference, provided the fodder was cut at the same period of development and the fodder retained its feeding qualities unmodified by keeping, especially when exposed to alternations of freezing and warm weather. These experiments were made with cows and gave the following results:

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
	73.3	43.8	81.6	56.7	75.0	78.2
	73.1	39.5	81.3	51.1	74.0	78.7
Average	73.2	41.6	81.4	53.4	74.5	78.3

The coefficients are very varying, but represent different fodders. I used one cut in the latter part of September and kept, as the most of our fodders are kept, in shock until used. The time of my experiment also corresponded to that at which this fodder would be used, so the results represent as nearly as possible the value of this fodder to the stockmen of the eastern part of the state. Considering that the North Carolina experiments were made with pulled fodder, blades and tops, while mine were made with the whole plant, it seems that the results obtained in my experiments

have really lost nothing of their general value, from the fact that the experiments were made with regard to special conditions.

I am inclined to doubt the claim which is sometimes urged against this fodder, that it changes rapidly, losing its feeding qualities. One must admit, however, that the coefficients given by the Texas Station experiments show a much higher degree of digestibility than either those of the North Carolina Station or my own. My experiments show that a large amount of dry matter was eaten per thousand of live weight, i. e., 30 to 31 pounds. The animals ate it freely enough, but each of the animals lost weight while feeding upon it. The aggregate loss was 7.5 pounds in five days; so that neither the coefficients found nor the weights of the animals at the end of the experiments indicate any great value for such sorghum fodder.

The animals fed upon it well, as the amount left as orts as well as the large amount of dry matter consumed indicate, and, so far as we could observe, they suffered no inconvenience from their being kept upon it as an exclusive diet for 12 days.

The variety of sorghum was Minnesota Early Amber, grown on sandy loam; sown May 10, cut September 15, stood in shock until following March. Weight of crop not given.

SALT BUSH. Atriplex Argentea.

Fodder Fed Sheep No. 4.

Weight of fodder received in five days, 6422.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.32	19.28	1.46	9.73	27.33	36.38

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
6080.38	1238.62	93.76	624.82	1755.75	2368.23

Orts, air dried, weighed 1547.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.24	15.61	1.07	7.23	39.57	30.28

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract
1450.47	241.41	16.55	111.82	612.12	468.43

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	6080.38	1238.62	93.76	624.82	1755.75	2368.23
Less orts	1450.47	241.41	16.55	111.82	612.12	468.43
Consumed	4629.91	997.21	77.21	513.00	1143.67	1899.80

Feces.

Air dried feces weighed 2655.1 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.53	10.53	1.32	6.27	40.44	34.91

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2481.78	279.51	35.04	166.41	1073.14	926.81

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	4629.91	997.21	77.21	513.00	1143.67	1899.80
Voided	2481.78	279.51	35.04	166.41	1073.14	926.81
Digested	2148.13	717.70	42.17	346.59	70.53	972.99
Co-efficients or percentages digested	**46.40**	**71.97**	**54.62**	**67.56**	**6.02**	**51.21**

Weight of the sheep at the beginning of the experiment 52.0 pounds.
Weight of sheep at the end of the experiment 50.0 pounds.
Daily consumption of dry matter equalled 3.9 per cent of the animal's weight.

SALT BUSH. Atriplex Argentea.

Fodder Fed Sheep No. 5.

Weight of fodder received in five days, 6422.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.32	19.28	1.46	9.73	27.33	36.38

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
6080.38	1238.62	93.76	624.82	1755.75	2368.23

Orts, air dried, weighed 761.0 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.84	13.96	1.16	7.18	40.17	31.69

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
716.56	106.23	8.83	54.63	305.61	241.11

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	6080.38	1238.62	93.76	624.82	1755.75	2368.23
Less orts	716.56	106.23	8.83	54.63	305.61	241.11
Consumed	5363.82	1132.39	84.93	570.19	1450.14	2127.12

Feces.

Air dried feces weighed 3102.1 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
6.36	10.18	1.37	6.49	38.66	37.01

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2904.89	315.71	42.50	201.34	1227.48	1148.11

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5363.82	1132.39	84.93	570.19	1450.14	2127.12
Voided	2904.89	315.71	42.50	201.34	1227.48	1148.11
Digested	2458.93	816.68	42.43	368.85	222.66	979.01
Co-efficients or percentages digested	**45.84**	**72.12**	**49.95**	**64.69**	**15.35**	**46.03**

Weight of sheep at the beginning of the experiment 58.0 pounds.
Weight of sheep at the end of the experiment 52.0 pounds.
Daily consumption of dry matter equalled 4.1 per cent of the animal's weight.

SALT BUSH. Atriplex Argentea.

Fodder Fed Sheep No. 6.

Weight of fodder received in five days, 6422.0 grams.

Analysis of Fodder.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.32	19.28	1.46	9.73	27.33	36.38

Fodder Constituents Fed, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
6080.38	1238.62	93.76	624.82	1755.75	2368.23

Orts, air dried, weighed 870.1 grams.

Analysis of Orts.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.57	14.88	0.99	6.42	42.32	29.82

Fodder Constituents Contained in the Orts, in Grams.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
821.46	129.41	8.61	55.86	368.24	259.41

Fodder Constituents Consumed, in Grams.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Fed	6080.38	1238.62	93.76	624.82	1755.75	2368.23
Less orts	821.46	129.41	8.61	55.86	368.24	259.41
Consumed	5258.92	1109.21	85.15	568.96	1387.51	2108.82

Feces.

Air dried feces weighed 2979.6 grams.

Analysis of Feces.

Moisture.	Ash.	Fat.	Protein.	Fibre.	Extract.
5.58	10.87	1.36	6.34	40.61	35.24

Fodder Constituents Voided.

Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
2813.48	326.62	40.49	188.71	1369.10	1049.27

Fodder Constituents Digested.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Consumed	5258.92	1109.21	85.15	568.96	1387.51	2108.82
Voided	2813.48	326.62	40.49	188.71	1369.10	1049.27
Digested	2445.44	782.50	44.66	380.25	48.41	1059.55
Co-efficients or percentages digested	**46.50**	**70.55**	**52.45**	**66.83**	**3.49**	**50.24**

Weight of the sheep at the beginning of the experiment 47.5 pounds.
Weight of the sheep at the end of the experiment 47.0 pounds.
Daily consumption of dry matter equalled 4.9 per cent of the animal's weight.

The Average Co-efficients of Salt Bush. Atriplex argentea.

	Dry Matter.	Ash.	Fat.	Protein.	Fibre.	Extract.
Sheep No. 4	**46.40**	**71.97**	**54.62**	**67.56**	**6.02**	**51.21**
Sheep No. 5	**45.84**	**72.12**	**49.95**	**64.69**	**15.35**	**46.03**
Sheep No. 6	**46.50**	**70.55**	**52.45**	**66.83**	**3.49**	**50.24**
Average	**46.25**	**71.55**	**52.34**	**66.36**	**8.29**	**49.16**

No data on the subject of the fodder value of the native salt bushes have come to my knowledge, so there are no results with which to compare these obtained with *Atriplex argentea*.

This salt bush is not to be mistaken for the Australian salt bush, *Atriplex semibaccata*, which plant differs materially from *Atriplex argentea*. The Australian salt bush has, I believe, been recommended by the California Station as a forage plant in alkali soils. I have made two preliminary tests with this plant, with results showing it to be better as it grows with us than the native silvery salt bush, but not a real good fodder. It probably would be a good plant for trial in the eastern part of the state where this silvery one grows. The Australian salt bush is an annual with us, which seeds itself abundantly.

The average digestion coefficients as found in these experiments with the silvery salt bush present some rather striking features. The coefficient for the dry matter is low, but it is evident that this must be the case when we observe that the crude fibre, constituting over one-quarter of the weight of the hay, is so good as indigestible.

The coefficient found for the nitrogen free extract is also low, but approaches the coefficients found for this constituent in hays, being, in fact, higher than in some of them. The ash in this plant is very abundant and its coefficient of digestion, 71.55,

is very high. The effect of this fodder upon the animals was very marked. The animals seemed to suffer no inconvenience, they looked as bright and contented as usual and chewed their cuds freely. There was no laxative, but a very marked diuretic action observed. I regret that I was not provided with facilities for collecting the urine. It would be interesting to know the amount voided and its nitrogen content. The water drunk daily by the same sheep varied from 1.5 to 4.5 pounds when fed native hay and a little salt, but this amount of water was increased to 10.5 to 15.0 pounds when they were fed on the salt bush and salt was withheld. Sheep No. 5 drank from 1.5 to 3.0 pounds of water when fed on native hay, but drank from 12 to 14 pounds daily when fed on the salt bush; but No. 6 drank the maximum quantities of water, from 13 to 15 pounds. There is no proof that the excessive amount of urine voided was due to the specific action of any substance contained in the plant, and it seems rather more probable that the large amount of saline matter taken into the system, 782.59 grams, a trifle over five ounces daily, provoked an intense thirst, as indicated by their drinking from three to eight times the amount of water usually drank by these individual animals, which flooded the system and had to be voided.

The weather at the time, the first week in June, was fine, the temperature of the water drank 13 deg.–14 deg. C.

Had the weather been cold and stormy and the water which the animal drank very cold, the results would have been less favorable than those observed. It must be kept in mind that this hay was put up for the purpose of feeding it to animals, already reduced in flesh and vitality, to take them over stormy periods. The general result of the experiment is not encouraging.

Some of the fodder constituents, the protein, for instance, show a comparatively good coefficient and there is a fair amount of it contained in the fodder. The same is true of the nitrogen free extract. The coefficient for the fat is good and compared with other plants there is a fair amount of it, but these good features of the salt bush as a fodder plant are offset by this thirst provoking and diuretic effect, whether the latter is consequent upon the former or not. I omit the composition of the ash in the hay and the feces, but may take it up in a later bulletin.

This bulletin is already longer than I desired it to be, and as each set of experiments summarizes itself I will not recapitulate the results here.

This bulletin will be followed very shortly by another, in which I shall take up some subjects omitted in this, i. e., the digestibility of the various extracts, alcoholic, aqueous, etc., together with the digestibility of the pentosans occurring in these fodders.

All of these hays and fodders have been cured and preserved

under Colorado conditions, and the animals used were the average grade of sheep fattened by the hundred thousand in this valley. Our results are as representative of our fodders and conditions as they can be made.

The coefficients found are not only lower than those usually given, but are lower than those given by investigators experimenting under very similar conditions. I have exercised every care to obtain correct results, and I believe that the coefficients of our fodders actually have a lower value than is usually given for the same fodders elsewhere.

Our fodders are seldom preserved under cover, but in stacks or shocks out of which they usually come as green, bright, attractive looking hays and fodders. They have, however, been exposed to our changes of temperature, our dry air and continuously strong light.

I believe that the results recorded in this bulletin are very close to the facts and would tentatively suggest that the coefficients of digestion for our hays and fodders are lower than the coefficients shown by the same fodders elsewhere. I do not know the reason for this, but believe that the manner of preserving the fodders, together with our climatic conditions, may account for it.

SUMMARY.

The average coefficients of digestibility found for corn fodder—a variety of dent corn—sown thickly and cut quite immature were: Dry Matter, 58.56; Ash, 42.84; Fat, 45.91, Protein, 47.38; Crude Fibre, 67.87; Nitrogen Free Extract, 57.60. The average coefficients given by Jordan and Hall for the immature fodder are: Dry Matter, 63.9; Ash, 37.2; Fat, 72.2; Protein, 51.7; Crude Fibre, 66.0; Nitrogen Free Extract, 66.2.

The second experiment with corn fodder, dent corn, drilled thinly in rows, cut August 20, some ears matured corn which were husked out before cutting to be fed, gave the following: Dry Matter, 56.66; Ash, 43.64; Fat, 66.08; Protein, 36.04; Crude Fibre, 56.71; Nitrogen Free Extract, 60.60. Jordan and Hall give the following coefficients for dent and flint corn (mature): Dry Matter, 68.2; Ash, 30.6; Fat, 73.9; Protein, 56.1; Crude Fibre, 55.8; Nitrogen Free Extract, 72.2.

It will be noticed that our coefficients are lower than the quoted ones, which are averages.

The average coefficients obtained for alfalfa hay in the first series of experiments were: Dry Matter, 52.04; Ash, 45.65; Fat, 90.85; Protein, 66.69; Crude Fibre, 47.76; Nitrogen Free Extract, 56.69.

The sample of hay used in this experiment contained an unusually low percentage of ether extract, 0.80, and was not a first-class hay, neither was it a decidedly inferior hay.

The second experiment in which a prime, first cutting hay was used gave the following: Dry Matter, 63.95; Ash, 57.67; Fat, 29.86; Protein, 72.54; Crude Fibre, 49.93; Nitrogen Free Extract, 72.89. The animals used in the first experiment were mature sheep probably 4 years old; those used in the second were young sheep, so-called Mexican lambs, about 1 year old.

The average digestion coefficients of first cutting alfalfa hay, which I obtain by using all the data available at this time, not including my own, are: Dry Matter, 61.00; Ash, 51.58; Fat, 53.81; Protein, 74.40; Crude Fibre, 47.11; Nitrogen Free Extract, 72.49.

There is here a substantial uniformity except in the case of the coefficient for the fat or ether extract, which we hold to be of little or no value, which is emphasized by the extreme results obtained in the first series of experiments. See remarks at conclusion of first series of experiments.

We mean to indicate by the negative sign that there was 90.85 per cent. more fat, ether extract, in the feces than in the hay eaten.

Native hay is seldom composed of the same mixture of grasses even if cut from the same ground, but in different years. It is therefore difficult to obtain comparable samples.

We obtained for a sample grown in the neighborhood of Fort Collins the following coefficients: Dry Matter, 59.78; Ash, 43.32; Fat, 47.09; Protein, 60.90; Crude Fibre, 61.36; Nitrogen Free Extract, 62.01; and for another sample grown in the Box Elder Valley about 23 miles north of the Poudre Valley the following: Dry Matter, 50.53; Ash, 42.52; Fat, 20.55; Protein, 62.33; Crude Fibre, 55.56; Nitrogen Free Extract, 51.30. The hay used in the second series of experiments seems to have been a decidedly less digestible one than that used in the first experiment; it represented a different mixture of grasses, the former consisting largely of Colorado blue stem.

Jordan and Hall give for meadow hay, with which our "native hay" is possibly more nearly comparable than with any other fodder, the following: Dry Matter, 54.3; Ash, 29.4; Fat, 44.7; Protein, 63.4; Crude Fibre, 54.5; Nitrogen Free Extract, 55.9.

Timothy hay is grown in large quantity in some of our mountainous districts and is of superior quality. We obtained as digestion coefficients for this hay, in the first series: Dry Matter, 56.71; Ash, 34.14; Fat, 31.88; Protein, 58.37; Crude Fibre, 54.61; Nitrogen Free Extract, 62.80. In the second series: Dry Matter, 51.03; Ash, 65.63; Fat, 69.32; Protein, 43.35; Crude Fibre, 36.08; Nitrogen Free Extract, 54.99.

These samples differed as much from one another as any two samples which we might purchase in the market would be likely to differ, as the second was purchased two years subsequent to the first and both would be properly classed as prime timothy hay.

Jordan and Hall gave the average digestion coefficients for timothy hay before and in bloom as: Dry Matter, 60.7; Ash 44.2; Fat, 58.4; Protein, 56.8; Crude Fibre, 58.8; Nitrogen Free Extract, 64.3. For timothy hay past bloom: Dry Matter, 53.4; Ash, 30.3; Fat, 51.9; Protein, 45.1; Crude Fibre, 47.1; Nitrogen Free Extract, 60.4.

The differences are marked in some instances but the agreement is as great as we have any right to expect.

The native hays are highly esteemed as feed for horses, commanding the same price in the market as timothy hay. If there is any choice the native hay receives the preference, while both are prefered before alfalfa, especially for livery and road animals. The results with the sheep are interesting in this connection. The fodders were fed alone, there was no mixed ration, but the sheep made a gain of 3 pounds each when fed alfalfa, the timothy scarcely maintained their weight, one sheep gained ½ pound, one sheep lost ½ pound and one lost 1 pound. The native hay makes a somewhat better showing as a fodder for sheep, two sheep gained ½ pound each, while the third one gained 2½ pounds in five days.

The result which will appeal to the public as most striking, so far as a digestion experiment can be depended upon to indicate the value of a fodder, is that obtained with the corn fodder. This fodder was not shredded, but simply cut as fine as we could conveniently cut it with a hand cutter, neither was it prepared in any manner, being fed dry, and yet the sheep showed a gain of 2 pounds, 1 pound and ½ pound respectively in the five days and the dry matter consumed per 100 weight of animal was less than of the other fodders.

The average digestion coefficients found for sorghum is for a fodder held until the spring of the year. The question which I had in mind when I undertook this particular experiment was what can our ranchmen in the eastern part of the state grow as a fodder to feed their cattle during the severe storms of late winter and spring when it is often necessary to tide the animals over trying periods. Sorghum promises to yield them as much fodder under their conditions as any other forage plant. The fodder, if it is used at all, must be shocked and kept till late winter or spring. It might have greater value if fed in the fall or early winter, but the experiments with it gave disappointing results so far as its feeding value was concerned, the sheep losing 3, 2.5 and 3 pounds respectively in five days.

The average digestion coefficients obtained were: Dry Matter, 58.46; Ash, 44.61; Fat, 64.87; Protein, 43.06; Crude Fibre, 49.23; Nitrogen Free Extract, 61.06.

There are but few recorded digestion experiments with sorghum fodder. An experiment with a goat gave the following: Dry Matter, 59.88; Ash, 17.64; Fat, 47.14; Protein, 59.46; Crude Fibre, 64.88; Nitrogen Free Extract, 62.51.

The salt bush atriplex argentea used by ranchmen in the eastern part of the state yields digestion coefficients as follows: Dry Matter, 46.25; Ash, 71.55; Fat, 52.34; Protein, 66.36; Crude Fibre, 8.29; Nitrogen Free Extract, 49.16.

These coefficients, that for crude fibre and consequently that for the dry matter excepted, are quite favorable, but as a fodder for sheep it is a failure if the weights of the sheep after their 12 days feeding on salt bush can be relied upon. The sheep were weighed at the beginning and end of their last 5 days feeding on this fodder, when we found that they had lost ½, 2 and 6 pounds respectively in this time.

This fodder provoked an intense thirst, the animals drinking from 10½ to 15 pounds of water a day and voiding an immense amount of very ill-smelling urine.

These same animals drank from 1½ to 4½ pounds of water daily when fed on other fodders.

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Bulletin 94. (Technical Series No. 6) December, 1904.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

REPORT OF THE ENTOMOLOGIST.

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PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO.
1904.

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FORT COLLINS, COLORADO.

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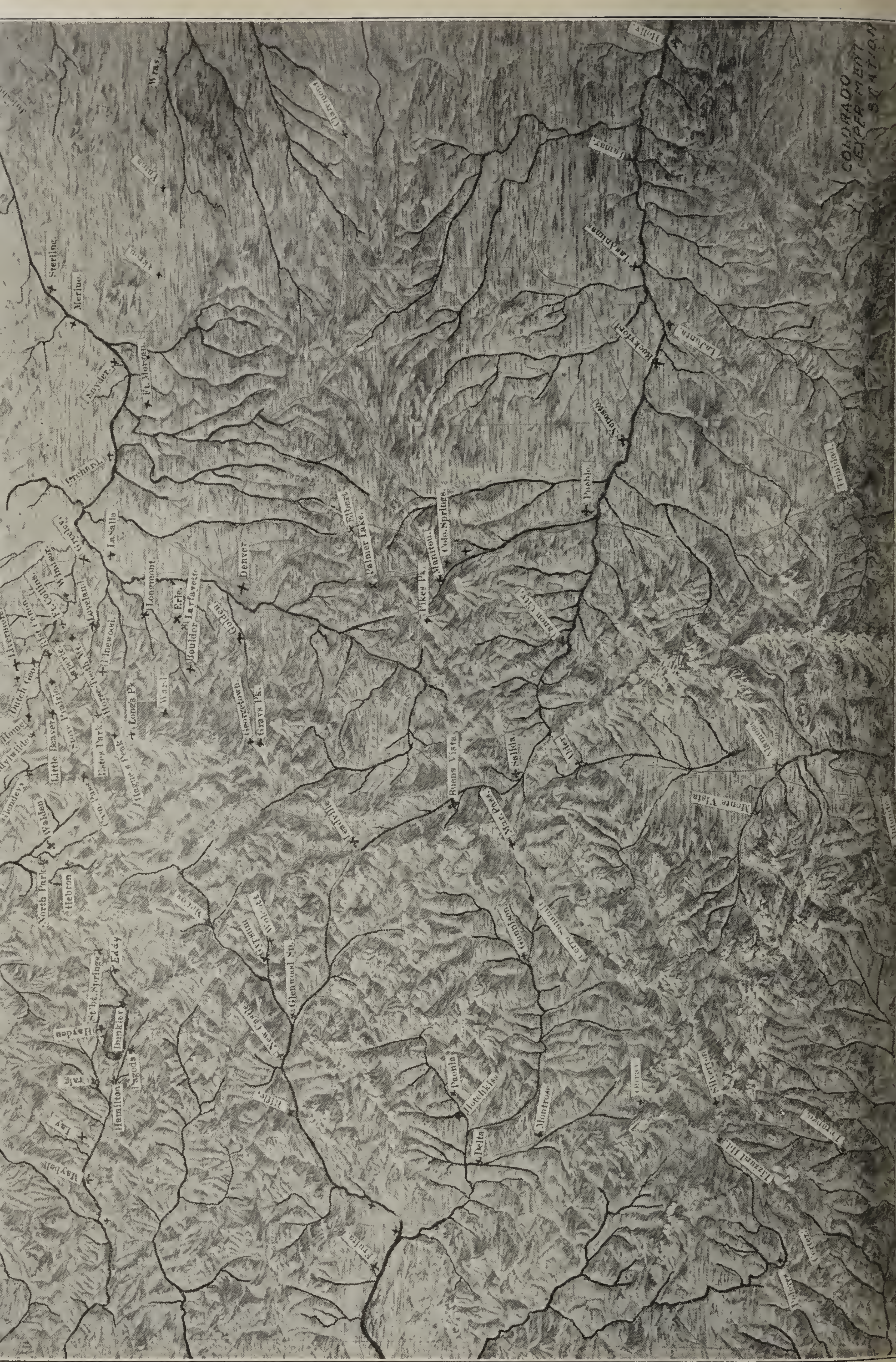

The **X**s east of Fruita on the Grand River are for Grand Junction and Palisades.

Some of the More Important Insects of 1903.

By CLARENCE P. GILLETTE.

GRAIN BUG.

The Grain Bug (*Pentama sayi Stal.**)

[Pl. I. Fig. H.]

Early in August complaints came to the Experiment Station of a large green bug that was doing extensive injuries to grain and other crops in Montezuma county. Mr. S. A. Johnson was sent to investigate the trouble. He went directly to Cortez and was greatly assisted in the work by Mr. P. S. Taylor of that place. The following is an extract from Mr. Johnson's report of what he found:

"Mr. Taylor took me to a number of fields of wheat and oats that had been injured by the green plant-bug. He says that the bugs appeared in great numbers in the fields of grain when they were just heading out where they accumulated upon the heads and seemed especially to suck the juices of the forming kernels. As the grain would reach maturity the bugs would migrate to other fields where the grain was not so far advanced. At present the attack is less severe, much of the grain having matured but still in most fields four or five strokes of an insect net will collect a handful of the bugs and many of the insects are upon the lower portions of the plants and upon the ground. The injuries in the grain fields are indicated by the presence of the blasted heads that have few or no kernels in them and which have ripened and turned white prematurely (see plate II. Fig. A.).

"The injury to oats was very severe. In some cases entire fields of grain appeared to be destroyed. Often the heads were blasted from the punctures of the bugs before they appeared above the leaf sheath.

"The insect seems to be a rather general feeder. It was reported upon first cutting of alfalfa, and upon sunflowers, sage and garden vegetables, especially peas. But very few were obtained

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*Determined for us by Mr. E. P. VanDuzee; also by Mr. Otto Heidemann, through the kindness of Dr. L. O. Howard.

sweeping alfalfa with the net and it seemed probable that those taken in this manner might have come from the weeds. In case of peas and beans the pods were chiefly attacked and the juices were extracted from the seeds within. A peculiar effect upon the peas was that the punctures introduced or prepared a way of entrance for a fungus which soon rendered all the seeds unfit for use.

"No one remembered having seen the insect in injurious numbers before and some believed that the insect had migrated into their midst from farther down the river where it was reported that the bugs were still more abundant, and where they did some injury last year."

The following letter giving an estimate of injuries in Montezuma valley was written by Mr. P. S. Taylor, Oct. 21, 1903, in reply to my letter of inquiry:

"The bugs first appeared in the valley about the 20th of May, coming from the southwest for three days in succession. These lighted mostly on alfalfa fields where they deposited their eggs, which hatched about two weeks later.

"The bugs remained on the alfalfa until the first cutting of hay was made. Then, (about the first part of July) they left the hay fields going to adjoining wheat fields where for a time they sucked the sap from the wheat plants. As soon as grain formed in the heads the bugs bored into it, drawing their nourishment from the soft grain. This they continued until the wheat either hardened or was killed.

"Leaving the wheat they attacked oat fields in August, working in the same manner as on the wheat. But the damage that was done to oats was not nearly so great as that done to wheat.

"By the first of September nearly all the bugs had disappeared and so far as I could determine there were no eggs deposited after the first lot in June. The damage was done almost entirely in the lower part of the valley, on an area of 725 acres where an average yield for the past eight years was 35 bushels per acre, or a total of 25,375 bushels. The yield of the past season on the same number of acres was 15 bushels per acre, or a total of 10,875 bushels. This would show a shortage of 14,500 bushels and a money loss at present prices of over thirteen thousand dollars.

"Some fields of grain were entirely destroyed while others were injured only in spots."

Respectfully yours,
P. S. Taylor.

The following is an extract from a letter received from Mr. M. V. B. Page, of Fruita, Colo., dated August 6:

"I am sending you samples of a bug that is destroying crops of all kinds but more especially potatoes, by sucking the sap from the stems of the plants. They are upon oats as well. They come in patches and then spread over the fields. I first discovered them in a small patch of ten acres of early potatoes a week ago and now they are all over the patch. I find no small ones; all seem to be of the size of the sample sent."

This bug is a close relative of *Liodermа uhleri* which was reported by Saunders in Bulletin 57 of the South Dakota Experiment Station and the habits of the two insects seem much alike. The species that has been so abundant in the southwestern portion of Colorado the past summer is generally distributed over the mountainous portions of the State and has frequently been taken

from native plants for the College and Station collections. Mr. C. R. Jones, a special student in entomology here, found this bug common above timberline at Silverton, Colo., the past summer where he was collecting. Specimens are seldom taken at Fort Collins.

The insect is single brooded.

There was a great advantage this year in having grain ripen early. Fall wheat escaped the injuries almost entirely.

GRASSHOPPERS.

The destructive grasshoppers (locusts) which are usually very numerous over a great portion of the agricultural section of the State were comparatively few in number this year except in limited sections. The previous year was marked by unusually severe grasshopper depredations and the small number of these insects the present year is probably due to the prevalence last year of the native grasshopper disease, *Empusa grylli* On the other hand, there has been very little of this disease among the grashoppers the past summer and fall.

The Australian Grasshopper Fungus, was experimented with again this year. Several tubes of the fungus were sent directly from the Colonial Bacteriological Institute of the Cape of Good Hope through the kindness of the director, Dr. Alexander Edington. The cultures were received in an excellent condition and were used in the field and in our breeding cages but in no case were we successful in killing any of the grasshoppers as far as we could determine. As this is the second year that we have worked with this disease without obtaining any apparent results, I can see no reason to encourage Colorado farmers to hope for relief from grashopper depredations through the use of the African grasshopper fungus (*Mucor sp.*)

A new grasshopper remedy known as "Criddle mixture" has been reported very efficient for the destruction of grasshoppers in Manitoba. It consists of a mixture of fresh horse manure, salt and Paris green which is distributed about the fields where the grasshoppers are numerous. In our experiments the ingredients were used in the following proportions:

Fresh horse manure	40 quarts.
Barrel salt	2 quarts.
Paris green	1 quart.

The preparation was repeatedly used in breeding cages and in field tests. In no case were the results very encouraging so long as there was green food obtainable. Poisoned alfalfa leaves and poisoned bran were used in comparison with the Criddle mixture and of the three the bran seemed most efficient. None of these preparations gave results that were very satisfactory.

Mr. Conrad Schaffer, an extensive and intelligent farmer living at Deuel, Colorado, decided to try the Criddle mixture and induced several of his neighbors to join with him and make a thorough test. In a verbal report to the writer on October 20, Mr. Schaffer said the mixture did but little good. He said he had much better results with a mixture of bran and Paris green that was moistened with just enough refuse syrup from a beet sugar factory to make the mixture adhere in small balls. These balls of poisoned bran were distributed about 20 feet apart along potato rows and in other places where the grasshoppers were abundant.

CUTWORMS.

The Army Cutworm (*Chorizagrotis auxilaris.**)
[Pl. I. Fig. A. B. C. D.]

which is usually as numerous as all other species put together in northern Colorado, occured in more than its usual abundance last spring. The moths have a strong propensity for getting into buildings whether there are lights inside or not. It is a common thing for these moths to appear in large numbers upon the insides of windows during May and June. The moths also conceal themselves among the leaves of trees during the day time. The abundance of the moths was especially remarkable during the summer of 1902 and many inquiries were received at the Station concerning them. A stick or a stone thrown into a tree when they were most numerous would often cause hundreds to fly out for a few seconds then they would return. They were such an annoyance about lamps in houses that the occupants of the home would blow out the lights and go to bed just to get away from the nuisance. So that the unusual cutworm invasion of the past spring was only the sequel of the abundance of moths the preceding summer.

This is the species treated by Dr. Wilcox in Bulletin 17 of the Montana Experiment Station. It is a native of the Rocky Mountain region. I have found the moths not uncommon in this State,near to timber-line under the loose bark of stumps.

Specimens of the spring brood of moths have been taken at the Station between April 16 and July 10,and are usually most abundant about the first of June. The fall brood has been taken from September 13 to October 12. A queer circumstance in connection with my studies of this moth is, I have never been able to find fully developed ova in the females of the first brood though hundreds have been dissected and examined. In the great majority of cases there has been no indication of ova in any stage of develop-

**Chorizagrotis auxilaris* having priority, I have included with it forms commonly determined as *introferens* and *agrestis* because in a larger series there seems to be every gradation between the three forms and because they always occur together and rise and fall together in numbers so far as my experience has gone. The specimens in the collection were determined by Dr. J. B. Smith; also by Mr. Otto, Heidemann through the courtesy of Dr. L. O. Howard.

ment. The females taken in the fall have, almost without exception, contained fully formed ova. Neither have I ever known the fall brood to be noticeably adundant, only occasional specimens being taken.

About the first of May there were several newspapers of the State reporting the presence of some kind of army worm in millions in different localities. On April 31 I went to Fort Morgan where extensive injuries from such an insect were reported. In company with Senator W. A. Drake, several farms were visited and the injuries of the worm noted. In one instance the Chapman brothers had sowed alfalfa seed in the spring of 1902 and secured a good stand and then the alfalfa suddenly disappeared, from some unknown cause,for a distance of four or five rods along the border of the field adjoining wild land. The strip was re-seeded May 28 and a good stand secured which grew thriftily throughout the summer. The past spring alfalfa in this field made a good start again and at the time of my visit it was rapidly disappearing. An examination showed the cause to be cutworms.

Another field of the previous year's seeding belonged to Mr. Burnett and seemed to be perfectly bare, but on examination the little alfalfa stocks could be seen everywhere, but the leaves and tender new shoots had all been eaten down by the worms.

On Senator Drake's farm a large field of virgin soil had been plowed and sowed to barley early in the spring. The barley came up nicely all over the field and then suddenly disappeared. To one driving past this field there was no evidence that there had been a green thing growing there a few days before. I went into the field and could not find a single spear of barley but upon digging down from one to two inches could find the stubs of the young plants and the worms. The senator told me later that the barley did not appear again so that the fields had to be replanted.

Other fields were visited and it soon became evident that there were two types of injuries. In some cases the fields of grain and alfalfa were attacked about the borders only, while in others the injuries seemed equally distributed throughout the field. A little inquiry revealed the fact that in all cases where the virgin soil had been plowed in the spring and seeded the injuries were distributed throughout the field, but where the virgin soil had been plowed the previous fall or summer, the cutworm injuries were only noticed about the borders of the fields and only those borders that were adjacent to wild land. Fort Morgan is in a grazing region and the ground is pretty well covered with a mixture of gramma and buffalo grasses which are evidently among the native food plants of this cutworm, in fact the worms were found feeding upon these grasses.

About the first of May reports began to come in of extensive injuries to sugar beets from cutworms. As near as could be determined not less than four or five hundred acres of beet land in Northern Colorado had to be re-seeded this year because of the ravages of cutworms. Next to virgin soil, the fields that were in grain the previous season seem to have suffered most and barley seems to have been the grain that attracted the moths for the deposition of their eggs far more than any of the others.

On May 29, in company with Mr. H. H. Griffin, one of the field agents for the Fort Collins Sugar Company, I visited Mr. John Hice's farm near Fort Collins. He partially plowed a field of barley stubble late last fall and then finished plowing in the spring and put the field in to beets. The beets on the fall-plowing were in very good condition, but upon the spring plowing they were so badly taken by the worms that it was decided to re-plow the entire field and seed again. At that date, May 20, the worms were fast disappearing and many pupæ could be found and fields seeded after this date were not seriously attacked by the worms. The spring was unusually late this year so that it is probable that in an ordinary season the cutworms would do little injury to beets after the 10th or 15th of May, or after the moths begin to appear upon the windows or about the lights of our houses. May 20th was the first date we noticed them upon our windows the past summer.

On May 30, Mr. S. A. Johnson went to Aurora, a suburb of Denver, to investigate cutworm injuries and was aided in the work by Mr. H. Rauchfuss, who had written the Station concerning the injuries by the worms. Mr. Johnson found the worms mostly full fed or in the pupa state. The worms were pupating about two inches beneath the surface in vertical burrows with the head of the chrysalis towards the mouth of the burrow. The earthen cells at the bottom of the burrow were quite firm though they could be crushed without difficulty between the thumb and fingers. A quantity of the worms were brought into the laboratory and placed in breeding cages for the purpose of rearing the moths and it was found that nearly half of the worms were parasitized. The majority of the parasitized individuals seemed to be entirely eaten out beneath the skin and to be packed full of minute pupæ of a species of *Copedosoma*. In one instance 1705 of the adults issued from a single worm. See Plate I. Fig. D. Two Ichneumon parasites (*Ichneumon longulus* and *Amblyteles subrufus*) were also bred from the worms.

Two pupæ and worms brought into the laboratory the last of April began appearing as moths June 26.

Plowing during the summer or fall and keeping the ground clean of all vegetation until winter will give almost perfect pro-

tection against these cutworms unless there are adjacent infested lands from which the worms may migrate into the borders of growing crops.

The clandestine cutworm, (*Noctua clandestina.*)

A dark brown, almost black species, without conspicuous markings upon the wings, is also common each year in the north-eastern portion of Colorado, at least. It is a little later than the preceding species, the moths appearing about the lamps as those of *Chorizagrotis auxilaris* are becoming scarce. I have never known it to be nearly so numerous as that species.

LEAF ROLLERS.

The Fruit-Tree Leaf-Roller (*Cacœcia argyrospila Walk.*)
[Pl. I. Figs. E and F.]

This insect in company with *Cacœcia semiyerena*, the boxelder leaf-roller, has an interesting history in Colorado. Thirteen years ago both were destructively abundant in Northern Colorado in the vicinity of Fort Collins and Greeley. Their numbers have gradually grown less in that portion of the State until the past year or two, when they have not occured in sufficient numbers to attract attention much north of Denver, while they are very destructive to the foliage of fruit and box-elder trees in that city and in the vicinity of Colorado Springs.

Many of the Tortricid moths vary greatly in color markings so that it is often impossible to distinguish between species without rearing the moths from single patches of eggs. There has been so much of this variation in the moths that I have been grouping under the name *C. argyrospila* that I decided to rear a few "families" from separate batches of eggs. Six egg-batches were placed in separate cloth sacks and each sack tied over a limb of a plum tree on April 23, when two of the patches, (numbers 1 and 5 of the following diagram) were beginning to hatch. These sacks were frequently examined and when the larvæ were nearly grown the contents of each sack were brought into the laboratory and placed in a separate breeding cage and the transformations noted until the moths all appeared. The records of the six cages are given as follows:

SUMMARY OF SIX BREEDING-CAGE RECORDS UPON TRANSFORMATIONS OF CACŒCIA ARGYROSPILA.

Cage numbers	1	2	3	*4	5	6
Began Hatching	April 23	did not		April 23		
First Pupa	June 2	hatch.		June 2	June 2	June 2
Last Pupa	June 13			June 17	June 11	June 20
First Moth	June 15		June 13	June 13	June 13	June 13
Last Moth	June 25		June 30	July 1	June 19	June 29

As egg-patches 3 and 4 were not hatching when placed in the sacks but gave pupæ and moths as early as any, it is to be presumed that they were not more than a day behind those in cages 1 and 5. This would make the shortest time from hatching of the egg to emergence of adult moth 50 days and the longest time 68 days. It is rather remarkable that in the four cases noted the first pupation occured on the same date, June 13. This would indicate about 11 days as the ordinary time spent in the pupa stage.

Moths bred from the same batch of eggs vary in color from a dark rusty red with only one conspicious pale yellow patch in the middle of the costal margin of the anterior wing to a light straw yellow with only faint indications of the rusty coloration outlined in a very light rusty brown. There is one typical pattern of the dark markings however, which can be traced through all the specimens. Figs. E. and F. Plate I. show twelve of these moths in two rows. All in the front row were bred from a single patch of eggs. Those in the second row are from two other patches. That all the moths from the five cages are of the same species is proven by the fact that each group has one or more moths that are exactly like some in all the other groups.

Experiments for the destruction of eggs. Several laboratory tests were made to determine the effect of certain insecticides upon the egg-patches early in the spring. They resulted as follows:

Kerosene emulsion that was one-third kerosene was applied to 6 egg patches. None of the eggs hatched.

Kerosene emulsion that was one-fourth kerosene was applied to 7 egg patches. One patch hatched well, one partially, 5 not at all.

Kerosene emulsion that was one-sixth kerosene was applied to 6 egg-patches. From one patch two larvæ emerged and from 5 none hatched.

Crude petroleum was applied to 5 egg-patches, and none hatched.

Whale-oil soap, 1 pound to 1 gallon of water was applied to 8 egg patches. Three hatched well, 2 partially and 3 did not hatch at all.

Whale-oil soap, 1 pound to 2 gallons of water, was applied to 7 egg-patches; three hatched well, one hatched about half, two hatched a very few, one did not hatch at all.

Whale-oil soap, one pound to four gallons of water was applied to six egg-patches; two hatched well and four did not hatch at all.

Lime salt and sulfur was applied to five patches; four hatched well and one did not hatch at all.

Whitewash composed of lime one pound, water two quarts, was applied to eight patches; one patch hatched well, five patches hatched about half of the larvæ and two hatched a very few.

Lime wash in the proportion of two pounds to three gallons of water was applied to seven egg-patches all of which hatched well.

Arsenite of lime in which there was about one pound of arsenic to 100 gallons of water was applied to six patches of eggs; one patch hatched well, three hatched about half the eggs, two hatched but very few.

Arsenate of lead in the proportion of a pound to five gallons was applied to 12 patches of eggs; five patches hatched well, two hatched about half of the eggs, two hatched a very few larvæ and three hatched none.

From these tests we are encouraged to think that crude petroleum and the stronger emulsions may be used quite successfully for the destruction of the eggs before the leaves appear in the spring, but whale-oil soap, whitewash, lime-sulfur-and-salt, and the arsenical poisons do not give much promise. Our whale-oil soap was very hard and probably not of good quality.

The Choke-Cherry Leaf-Roller (*Cenopsis testulana Zell.*)

Pl. I. Fig. G.

This leaf-roller is occasionally quite abundant among the small choke-cherry bushes in the foothills near Fort Collins where it builds extensive and rather loose webs. It is also an extremely variable species. In some the fore wings are pale yellowish brown almost without dark markings, in others the fore wings are a deep and rather dark rust-brown without any signs of light markings while a majority have sulfurous yellow back-ground more or less heavily marked with rust-brown. See the third or lower row of moths in Plate I. Fig. G.

BEET WEB-WORM (*Loxostege sticticalis Linn.*)*

[Pl. I. Fig. I.]

On July 11th the writer was called to investigate the injuries being done by a horde of small striped caterpillars to onions and cabbages on a farm near Fort Collins. On visiting the farm in question it was found that in the center of a large field there was a small area, perhaps an acre, that was above irrigation and which, being neglected, had grown up to lamb's quarter. Upon these weeds the worms had fed until the plants were brown and dry. The worms then left the dead weeds and marched out like an invading army into the cultivated crops of onions and cabbages which they were devouring very rapidly at the time of my visit.

*Determined by Mr. Coquillett through kindness of Dr. L. O. Howard.

Two days later, word came to the Station that some worm had appeared in great numbers in many of the fields of young beets. A ride through the infected area in company with Mr. Charles Evans, manager of the Fort Collins Beet Growers' Association, revealed the fact that nearly if not quite all of the injuries from worms were to fields that had been plowed in the spring. In most of these fields considerable alfalfa was growing at the time of our visit.

To avoid such injuries as the above, do not allow lamb's quarter (*Chenopodium sp.*) to grow in proximity to other crops, and, in case alfalfa ground is to be put in to cultivated crops it would be better to plow the previous fall, but in any case keep the ground sufficiently cultivated to keep down any growth of alfalfa which might attract the moths for the purpose of egg-laying early in the season.

THE GOOSEBERRY FRUIT-WORM (*Dakruma Convolutella*) (?)

The gooseberry fruit-worm has become a serious pest, especially to currants, along the foot hills of the eastern slope in this State. It is not uncommon to hear that this insect has destroyed the greater portion of the crop. It also feeds freely upon a common wild currant, *Ribes aurium*, which grows in the foothills, a fact which adds much to the difficulty of keeping the pest in check.

PLANT LICE (*Aphididæ.*)

Several species of plant lice were extremely abundant again during the past summer. Various insecticide substances have been used experimentally against these lice both in the egg and in the later stages and a press bulletin, No. 20, entitled "Plant Lice and their Remedies," written by Mr. S. Arthur Johnson has been issued by the Station.

The apple plant louse (*Aphis pomi*) has been extremely abundant and quite destructive to small trees in some localities. For several years past there have been many trees, particularly small ones, that have had many of their small limbs literally blackened with eggs of this insect. Such trees are common in the orchards of Northern Colorado during the present fall. I have observed such trees for several years and have never known more than a very small fraction of the eggs to hatch in the spring. In fact in some cases I have been unable to find that any of the eggs upon a tree have hatched. I am confident that not more than one egg in a thousand hatched in the vicinity of Fort Collins last spring and yet by the middle of June the lice were common in orchards and gradually increased in numbers so that from the middle of July on through the summer the lice on the apple trees of this section were exceedingly numerous. I have never seen any evidence that

this louse has an alternate food-plant in Colorado, at least it is continuously upon apple,and pear trees from the opening of the leaves in spring until the eggs have been deposited in October and November.

The green plum louse,(*Aphis pruni*,) the black cherry louse, (*Myzuz cerasi*,) the boxelder louse (*Chaitophrous negundinis*,) the snow-ball louse (*Aphis viburni*) and the woolly louse (*Schizoneura lanigera*) of the apple, were all of them specially abundant. The beet-root louse (*Tychea brevicornis*) has been reported by Mr. P. K. Blinn, field agent for the Station in the Arkansas Valley, as quite generally distributed in the beet fields in the vicinity of Rockyford and as attacking the roots of many weeds. He reports a louse that seems to be this species as very abundant and quite injurious to the common garden purslane. One beet field of eight acres near Fort Collins, investigated by Mr. Johnson, has been badly infested by this louse and, apparently, the crop has suffered considerably from it.

A full report upon the results obtained from the use of insecticides for the destruction of the lice and their eggs will be given in a bulletin later, after farther tests have been made. I may say here that we seem to have been entirely successful in destroying eggs of the lice with strong applications of kerosene emulsion, crude petroleum or whale-oil soap, made early in the spring.

FALSE CHINCH-BUGS (*Nysius minutus and N. californicus*).

These two species of false chinch-bugs are abundant in Colorado and their combined attacks upon mother beets in the Arkansas valley make it almost impossible to grow beet seed there. Mr. P. K. Blinn, writing under date of June 29, 1903, said he had just collected in one hour's time 20 pounds of these bugs from a patch of mother beets by brushing the insects into a dish held in the hand. Mr. Blinn also reported radishes, and mustard, planted near the beets as trap crops, of no value as the bugs were as abundant on the fields of beets as on the trap crops. He also stated that mother beets grown in a field surrounded by oats were not injured by the bugs. These bugs seem partial to plants of the mustard and goose-foot families and I do not remember to have seen them attacking any of the grasses. It is possible that any of the grains would afford barriers that would be rather effectual in excluding them. Wild mustard is a favorite food-plant for these false chinch-bugs. About nine-tenths of the specimens received from Mr. Blinn from beets were (*N. minutus*.)

Some have thought these insects to be the chinch-bug of the prairie states farther east, but such is not the case.

WESTERN WHEAT-STEM MAGGOT, (*Pegomyia cerealis* n. sp.*)

On the 5th of last May complaint came to this office that a wheat field that was looking all right ten days before had, for some reason, died down badly. Mr. Johnson went to examine the field and returned with a quantity of wheat stems with maggots in their centers. There were ten acres in the field and the injuries were so severe that it was decided that all would have to be plowed under, which was done, and the field planted to sugar beets. The field had been sown to wheat for three years in succession and had been fertilized heavily with barnyard manure the past fall and sowed to winter wheat which grew but little in the fall but which made a fine stand in the spring.

The maggots burrow down the centers of the stems and feed where the latter are most tender, an inch or two beneath the surface of the ground. At the time of examination, May 5, many light colored dipterous pupæ were found an inch or two beneath the surface close to the plants upon which they had been feeding. These pupæ brought into the laboratory began giving flies June 6. The early appearance of pupæ in the field makes it seem likely that the eggs may have been laid the previous fall. If this was not the case, the flies must have emerged very early in the spring.

DESCRIPTION.

The maggots are dirty yellowish white in color and measure between 6 and 7 mm. in length by 1.5 to 1.75 mm. in diameter. At the small or anterior end the two jaws show distinctly and at the posterior end the two spiracles are black and above them is a shining black plate or chitinous piece which terminates in two short stout spines. The puparium is like the maggot in length and thickness, it is straw-yellow at first but darkens rapidly as the time for the emergence or the fly draws near. The black plate and spines of the maggot also show plainly and the extreme anterior end is blackened.

The Adult Flies. Female: length about 5.5 mm. exclusive of ovipositor. Color of head and body rather uniform light gray, set with large and small black bristles that arise, each from a small black spot. Eyes dark reddish brown, naked, separated in front by a space nearly equal to the diameter of an eye; antennæ black, the aristæ also black and slightly plumose to the tips. Color of head like that of thorax except for a slight golden tint upon the face. There are five moderately stout bristles in a row parallel with the inner margin of the compound eye on either side and another row of about 20 of these bristles along the posterior border of each eye, the two at the upper angle of the eye being larger than the others. On the thorax there may be distinguished one median and, on either side, two lateral darker stripes which are quite distinct, and upon each of which a row of stout black bristles arises. Scuttelum with four setæ, two very stout ones near the tip and one not so large near each posterior angle. Abdomen rather thickly set with stout black setæ of moderate size, the largest ones arising from near the posterior margin of the segments. Femora cinereous like the body except at the knees where they change to light amber which is the color of all the tibias; the tarsi of all the legs are deep black. The wings are hyaline, tegulæ and sub-tegulæ small and nearly equal and amber in color, as are all the large veins.

*Specimens submitted to C. W. Johnson were referred to Mr. Coquillett, who determined them, "Near *Pegomyia ceptorum*, but apparently distinct."

The males differ from the females in being of a dark cinereous brown color. The femora are also of the same color and the tibiæ are much darker than in the female. The eyes are very much larger being sub-attingent in front of the ocelli.

Described from nine males and ten females bred from stems of winter wheat.

The injuries of the fly seem to have been confined to the one field. Mr. S.A. Johnson and Mr. Fred Bishopp examined a large number of fields of winter wheat in the vicinity of Fort Collins but in no case did they find farther injuries by this insect.

The summer and fall habits of this fly are unknown.

A wing of this fly is shown in Fig. C., Pl. II.

Aspidiotus forbesi. A card from Prof. T. D. A. Cockerell, of Colorado College,states that he has found this scale abundant upon a bush of *Cercocarpus parvifolius* growing upon a hillside at Colorado City. This is a matter of sufficient importance to warrant mention of the fact in this report. It seems to be the first record for the species in Colorado.

(Explanation of plates.)

Plate I. A, B, C, three forms of the army cutworm moth (*Chorizagrotis auxilaris;*) D, two living cutworms, a chrysalis, a dead parasitized cutworm and two earthen cells of the same species; E, moths of *Cacœcia argyrospila* (fruit-tree leaf-roller), all bred from one patch of eggs to show variation in markings; F, moths of the same species selected from specimens bred from two patches of eggs; G, choke-cherry leaf-roller (*Cenopis testulana* Zell.), all from one tent showing variation in color; H, Grain-bug, *(Pentatoma sayi* Stal), and wheat kernels shrunken from attack of the bug, also two plump kernels for comparison; I, two larvæ of web-worm (*Loxostege sticticalis* Linn.)

Plate II. A, head of oats blasted from attacks of grain-bug (*Pentatoma sayi*), only three developed kernels; B, apple injured and deformed from application of too strong spray of Paris green; C, wing of western wheat stem-maggot *(Pegomyia cerealis)*.

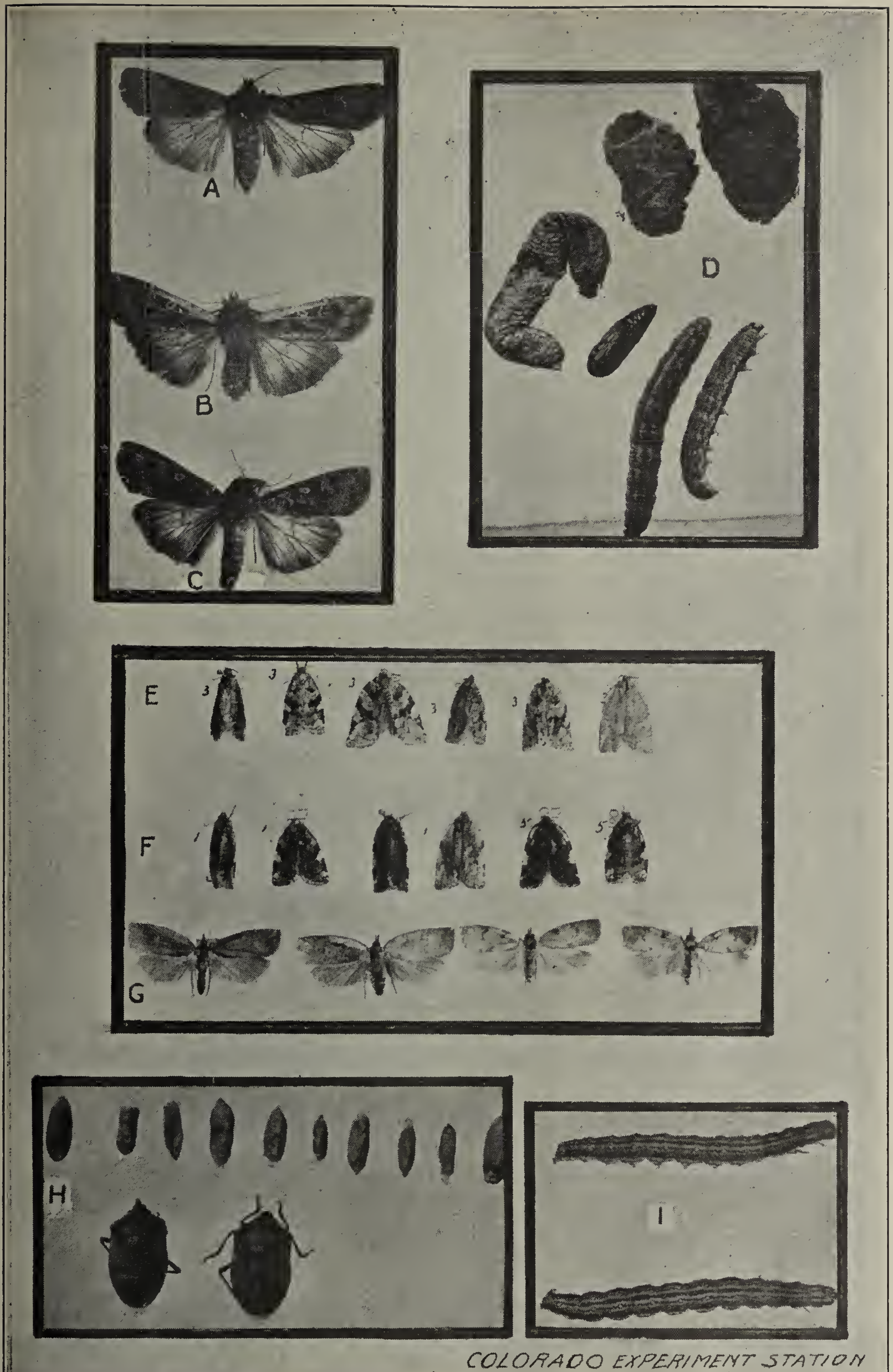

PLATE I.

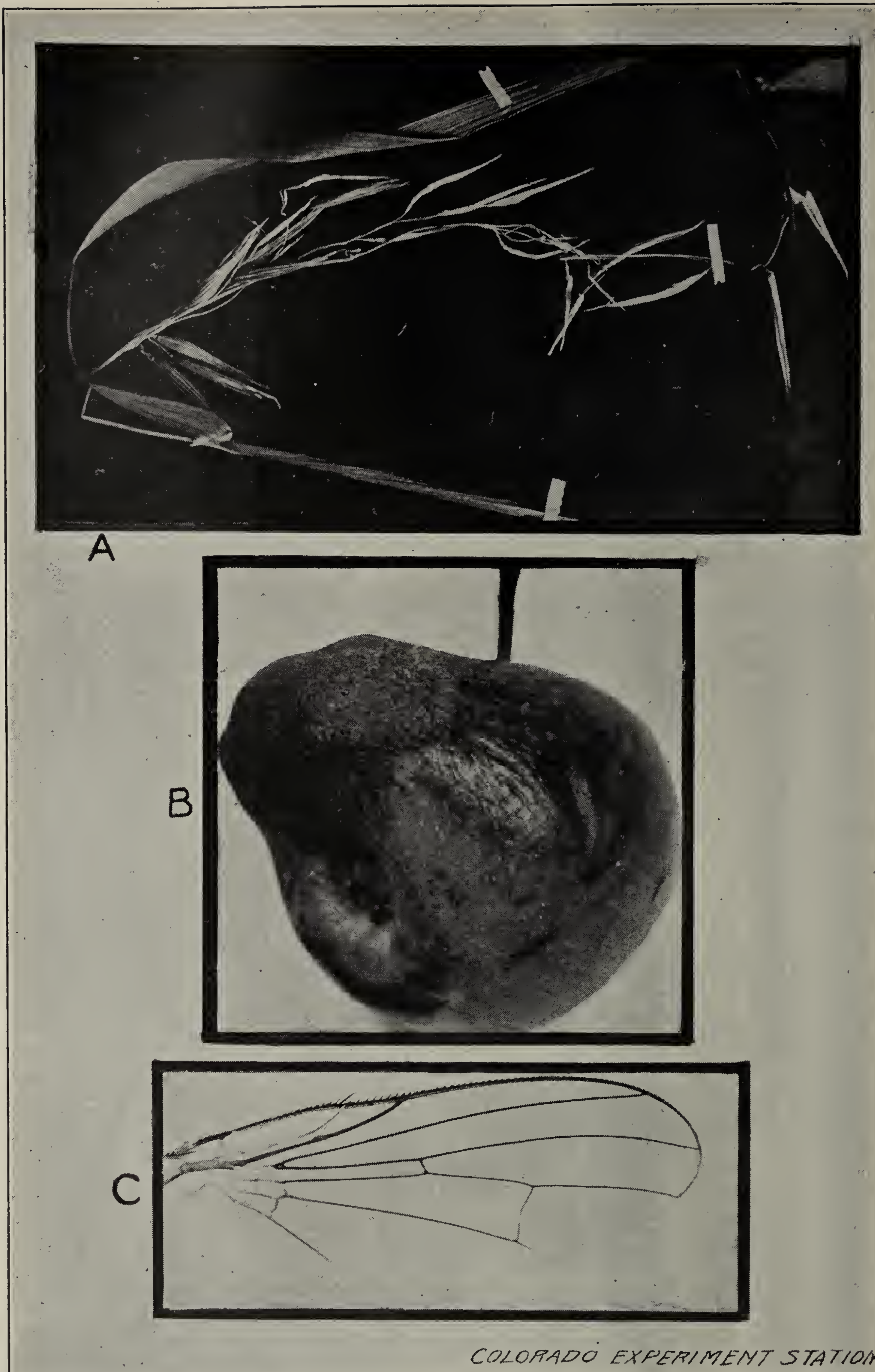

PLATE II.

Annotated List of Colorado Orthoptera

From Material in the Collections of the Colorado Agricultural College and Agricultural Experiment Station.

PART I.

Including Families Forficulidae, Blattidae, Mantidae, Phasmidae and Acridiidae

BY CLARENCE P. GILLETTE.

INTRODUCTION.

Since coming to Colorado about thirteen years ago, the writer has done what he could to make the rich and varied insect fauna of the State known to the world. First, the Cynipidæ were published upon in the *Canadian Entomologist* and in *Entomological News* during the years 1892, '93 and '94. Then Bull. 31, "A Preliminary List of the Hemiptera of Colorado," by Gillette and Baker, was published by the Experiment Station in 1895. In 1898 Bull. 43 was issued giving a list of the Lepidoptera in the College collection with the accessions notes upon them and also giving descriptions of a few new Jassidæ from the State; and the same year the writer prepared a monograph of the "American Leaf-hoppers of Subfamily Typhlocybinæ" which appeared in Vol. XX of the Proc. of the National Museum which included much Colorado material. When Prof. E. D. Ball came to this department as first assistant in 1897 he had already become a writer upon the family Jassidæ and was encouraged to continue his systematic work with this group, with a special view of working up the Colorado fauna, and his articles since that time have added much to our knowledge of Colorado Hemiptera. Mr. E. S. G. Titus wrote his thesis for the degree of M.Sc. upon "Colorado Bees," a bound copy of which is in the College library; and Mr. Titus also wrote numerous articles treating of Colorado bees that were published in the *Canadian Entomologist*. Our entire College collection of Colorado Coleoptera were sent to Prof. Wickham to be used by him in making out his list of Colorado Coleoptera which he published in the *Canadian Entomologist*. Many other papers have appeared from the pens of other entomological workers in which they report upon insects

from the collection of the Colorado Agricultural College and the present paper is another attempt to add to the existing knowledge of the insect fauna of the State. I hope to follow this paper at no distant date with another giving our records upon the remaining families of the order Orthoptera.

It is hoped that the present paper will be found fairly free from errors in determinations. There are still a few species of Acridiidæ not reported because of uncertain identifications and it is probable that, in a few instances, I have included under one name forms that have been considered distinct but which I could not separate except from differences in size or coloration.

BROODS.

All of our records point to one conclusion, and that is that all the species here reported are probably single-brooded.

The number of species reported in this paper are:

Forficulidæ	0
Blattidæ	5
Mantidæ	5
Phasmidæ	2
Acridiidæ	133
Total	145

DISTRIBUTION AND BARRIERS.

There are almost no cases where sharp lines of limitation in this State shut in the distribution of a species. The Continental Divide, and the line made by the sudden breaking of the eastern plains into the foothills and canons of the eastern slope, come nearest to being such barriers; and a few species seem rather closely confined to the area lying above timberline upon the mountain ranges. As a general rule, species that occur over the eastern plains also occur for some distance into the mountainous region but they seldom range higher than 7,000 or 8,000 feet, and many of the plains species occur but a very short distance in the hills. On the other hand mountain species that are common at 9,000 and 10,000 feet altitude are seldom found outside the foothills. Some species occurring abundantly above timber-line may be found all the way to the base of the eastern line of foothills, and *Blattella germanica*, that thrives so well at the sea shore, is equally prolific and aggressive in eating houses at mines located above timberline in the mountains. There are very few species except those that follow in the wake of civilization, that occur upon both the eastern and western slopes of the Continental Divide. A few species from the south and east have found their way up the Arkansas valley into the southeastern portion of the State that we have not found elsewhere,and several species occurring in the Platte valley of the

northern plains region we have not found occuring in the valley of the Arkansas.

The frontice piece is a map giving the main river systems and water sheds of Colorado with the points named where our collections have been made. Upon page 20 I have given a list of the places where collecting has been done, with their altitudes, and with each species I have given all the localities from which it has been taken by us. The reader will thus be able to make out the distribution of such species so far as determined by our records.

ACKNOWLEDGMENTS.

DETERMINATION OF SPECIES.

The Blattidæ here reported have been determined by Prof. Lawrence Bruner or by comparison with examples named by him. The Mantidæ and Phasmidæ have been determined by Professor Bruner, A. N. Caudell or E. D. Ball. The entire collection of Tettiginæ has been through the hands of Prof. Albert P. Morse and are reported as named by him. The remainder of the Acridiidæ have been named very largely by comparison with examples of the various species that were determined for the College by Prof. Bruner or Dr. S.H. Scudder, to whom doubtful and unknown species have been referred. The more readily determined species have been named by E. D. Ball or the writer. All errors are chargable to me, as I have worked over the entire collection during the past year, adding many species and many new records and changing many names. Prof. Morse has also determined several species of Trimerotropis and Spharagemon for me.

COLLECTORS.

The collection upon which this report is based has been accumulated during the past thirteen years as the result of the efforts of many helpers. An examination of 1,500 entries upon the Accessions Book shows that about 50 per cent. of the records are from collections and observations made by E. D. Ball, about 25 per cent. by the writer, and the remaining 25 per cent. by others, most prominent among whom are S. A. Johnson, E. S. G. Titus, E. P. Taylor, F. C. Bishopp and C. F. Baker. I have also received several species from Prof. T. D. A. Cockerell from the vicinity of Colorado Springs and Pike's Peak.

The original plan was to publish this report in joint authorship with Prof. E. D. Ball who was, at the time, my first assistant; but after his appointment to the Chair of Animal Biology in the Agricultural College of Utah, this plan had to be abandoned. I wish specially to acknowledge my obligations to Prof. Ball for the large

amount of work which he did in collecting material and data and making determinations preliminary to the preparation of this report.

The photographic reproduction of the topographical map of Colorado shown in this report is used with the permission of the "Continental School Supply Company" of Denver who own the original map.

PAPERS.

I am under special obligations to Professor Lawrence Bruner, and Professor T. D. A. Cockerell for permission to publish their papers describing Colorado insects in this report.

LOCALITIES AND THEIR APPROXIMATE ALTITUDE.

Akron (G)	4,650	Grand Junc'n (G)	4,594	Montrose (G)	5,811
Alder (G)	8,500	Gray's Peak (G)	10,000	Nepesta (B)	4,400
Alamosa (B)	7,540	Greeley	4,637	New Castle (G)	5,562
Alma	10,240	Gunnison	7,685	North Park	8,500
Antonito	7,889	Gypsum (G)	6,325	Orchard (B)	4,591
Bald Mountain	8,500	Hague's P'k (S)	11,000	Ouray (G)	7,706
Boulder (G)	5,300	Hamilton (J)	6,400	Palisades (G)	4,741
Buena Vista (B)	7,967	Hayden (J)	6,800	Palmer Lake	7,237
Cameron Pass (B)	10,000	Hebron (J)	8,500	Pagoda (J)	6,500
Canon City (G)	5,343	Holly (B)	3,400	Paonia (G)	5,500
Cerro Summit (G)	7,968	Home (B)	9,000	Pinewood (B)	8,000
Chama (N M.)	7,863	Idylwilde (J)	9,000	Pueblo (B)	4,668
Claremont (G)	3,650	Julesburg	3,456	Rico (B)	8,737
Colorado Springs	6,000	La Fayette (G)	5,179	Ridgway (Jo)	7,500
Cortez (J)	7,000	La Junta	4,061	Rifle	5,310
Craig (J)	6,500	Lamar	3,600	Rist Canon	5,500
Delta (G)	4,980	La Salle	4,663	Rocky Ford	4,177
Denver	5,200	Laporte	5,200	Salida (G)	7,050
Dolores (J)	6,957	Las Animas (B)	3,900	Silverton (Jo)	9,224
Durango	6,520	Lay (J)	6,163	Snyder (B)	4,160
Dutch George's (B)	7,000	Leadville (G)	10,200	Steamboat Spr'gs	7,300
Eddy (G)	7,000	Little Beaver	9,000	Sterling	3,920
Elbert (G)	6,710	Livermore	6,000	Stove Prairie	7,500
Erie (G)	8,179	Lizard Head (B)	10,200	Timnath	4,950
Estes Park (G)	8,000	Long's Peak (G)	11,000	Trinidad	5,980
Fort Collins	5,000	Loveland (G)	5,000	Walden (J)	8,500
Fort Morgan (B)	4,263	McCoy (G)	7,300	Ward (B)	10,000
Fruita (G)	4,500	McElmo (G)	6,800	Wheat Ridge	5,300
Georgetown (G)	8,476	Manitou (G)	6,200	Windsor (G)	4,900
Glendevy (J)	9,000	Marshall Pass (G)	10,856	Wolcott (G)	6,976
Glenwood Sp. (G)	5,758	Maybell (J)	6,000	Wray (B)	3,500
Golden (G)	5,700	Merino (B)	4,021	Yuma (G)	4,128

The altitude given in each case is that of the town or place itself. The grasshoppers referred to the different places were often taken at much greater altitudes. Silverton, for example, has an altitude of 9,224 feet but the insects referred to Silverton were taken on a mountain near by at an altitude of over 12,000 feet. This will account for my giving altitudes farther on in this

paper, for the occurrence of some of the species much higher than the altitude of any of the stations where the species was taken.

NOTE—Names of places followed by the capital (B) were collected in by Prof. E. D. Ball only; those followed by (J) were collected in by Mr. S. A. Johnson only; those followed by (S) were collected in by Dr. J. W. Skinner only; those followed by (Jo) were collected in by Mr. Charles Jones only, and those followed by (G) were collected in by the writer only.

Family FORFICULIDÆ.

We have not taken a representative of this family within the State.

Family BLATTIDÆ.

BLATTELLA Caudell.

germanica Linn. Specimens in the College collection are from a boarding house in Ft. Collins and from a boarding house at a mine near Silverton at an altitude of 12,000 feet, where they where very numerous in both instances,and a single specimen from a hotel at Leadville.

NYCTOBORA Burmeister.

holosericea Klug. One male and one female taken at Ft. Collins, June 5th, 1900.

mexicana Sauss. Occasionally introduced upon bunches of bananas from the south.

PERIPLANETA Burmeister.

americana Linn. A few examples from Ft. Collins and Denver.

orientalis Linn. One specimen taken at Golden, Colo., April 30th, 1902.

Family MANTIDÆ.

YERSINIA Saussure.

solitaria Scudd. Specimens of what seems to be this species have been taken at Ft. Collins, Palmer Lake, Durango and Alder. They have been taken in open places running about in short grass and so imitating the ground and dry leaves that they are never seen until they move. Rare.

LITANEUTRIA Saussure.

borealis Brun. Specimens of this species have been taken at Ft. Collins, Dutch George's, Holly and at Stratton and Kimball in Nebraska. Rare in Colorado.

minor Scudd. This species probably occurs quite generally over the plains region east of the foothills and a few miles into the hills, on dry grassy ground. Specimens have been taken at Ft. Collins, Dutch George's, Greeley, Pueblo and Trinidad.

obscura Scudd. A few specimens of what seems to be this species have been taken on the western slope at Grand Junction.

STAGMOMANTIS Saussure.

carolina Linn. A few specimens have been taken at Nepesta and at Grand Junction.

Family PHASMIDÆ.

DIAPHEROMERA Gray.

veliei Walsh. Taken at Holly, Sept. 8, '98, on corn, and at Julesburg Aug. 7, 1902 on grass on low ground. Rather common in both instances. (Ball.)

PARABACILLUS Caudell.

coloradus Scudd. A few specimens have been taken at Ft. Collins both inside and outside the foothills. In one instance two specimens were taken from a species of *Eriogonum*, July 27, '99. One of these was mature and one immature. We also have specimens from Kimball, Neb., taken Aug. 5th, 1899.

Family ACRIDIIDÆ.

TETTIX Charpentier.

acadicus Scudd. A single specimen taken at Steamboat Springs July 16, 1894. (Baker.)

crassus Morse. A common species in northeastern Colorado on low ground adjoining the foothills and near the streams in the canons. The adults hibernate during the winter among dead leaves. Most of the adults have been taken in the fall and early spring. This species varies much in color and in the length of the pronotum. Species taken at Ft. Collins, Laporte and Steamboat Springs only. Most of the specimens were taken in the foothills near Laporte.

hancocki Morse. Four specimens, all taken in Rist Canon near Laporte, June 15, 1898. (Ball.)

incurvatus Hanc. One specimen from Rist Canon, near Laporte, June 15, 1898, one ten miles farther back in the foothills July 21, 1898 (Ball.); and one specimen at Salt Lake, Utah, 6-16-'00. (Gillette.)

tentatus Morse. Two species taken at Little Beaver, 7-19-'98 at about 9,000 feet altitude, (Ball.); and two specimens taken in Estes Park, one July 11, and one July 15, '94, (Gillette). The last two named were rather immature. Altitude about 8,000 feet.

PARATETTIX Bolivar.

cucullatus Burm. A few specimens have been taken from the plains and foothills in the vicinity of Ft. Collins and a single specimen was taken at Lamar. The dates are in the months May and June.

tolticus Sauss. Four specimens, three taken in Rist Canon near Laporte, June 26, 1898, (Ball.); and one taken along the river near Ft. Collins 6-12-'97. (Gillette.)

MERMIRIA Stal.

bivittata Serv. Common over the entire eastern portion of the State to some distance within the foothills. This species seems to prefer the higher ground and is often abundant upon hill-tops. We have recorded specimens from Ft. Collins, Laporte, Windsor, Greeley, Orchard, Julesburg, Wray, Rockyford and Holly.

We have taken adults at Ft. Collins as early as July 10th and as late as Sept. 10th. They doubtless continue much later.

neomexicana Thom. This specimen seems to cover about the same ground as the preceding though it is much less abundant

We have specimens taken at Ft. Collins, both within and outside of the foothills, and also a few specimens taken at Rockyford, Holly and Nepesta. Our captures have all been made during August and September.

ACROLOPHITUS Thomas.

hirtipes Say. We have found this species most common in the gulches of the outer foothills and upon the dry hillsides. It probably occurs in small numbers over most of the plains of the eastern portion of the State. At Ft. Collins adults begin to appear about the last week in June. All our specimens have been taken before the last of August. Most of them are uniformly green in color but several individuals have a lighter shade, varing from light green to almost white upon the elytra and pronotum. Upon the elytra the lighter color is so distributed as to leave the green, for the most part, in round or oval blotches.

Specimens from Ft. Collins, Laporte, Livermore, Dutch George's, Wray, Greeley, Boulder, Golden, Las Animas and Coolidge, Ks. July 7, '02 all adult and eggs mature at Laporte. (Ball.)

ERITETTIX Bruner.

navicula Scudd. Specimens answering to the discription of this species seem not to be specifically distinct from *tricarinatus*. Perhaps Caudell is correct in thinking all the Colorado forms are *navicula*. See "note on Orthoptera, etc." by A. N. Caudell, Proc. U. S. National Museum, Vol. xxvi.

tricarinatus Thom. A common species on dry grass land in the eastern portion of the State and extending some distance into the foothills. Most common northward and near the foothills. Adults taken in northern Colorado from May 11th to August 13th.

Specimens have been taken at Ft. Collins, Laporte, Dutch George's, Virginia Dale, Livermore, Boulder, Palmer Lake, and Pueblo.

variabilis Brun. This species seems to be very generally distributed over the State up to an altitude of about 6,000 feet. We have taken it on grassy areas. It seems to feed mostly upon salt grasses. Adults were just beginning to appear at Ft. Collins June 22, 1899 (Ball) and we have taken them up to Sept. 23rd.

Specimens have been taken at Ft. Collins, Laporte, Windsor, Timnath, Greeley, Merino, Snyder, Julesburg, Boulder, Denver, Pueblo, Nepesta, Rockyford, Lamar, Holly and Delta.

AMPHITORNUS McNeill.

bicolor Thom. A very common species on dry grassy slopes over all the eastern portion of the State, particularly, northward near, and for some distance within the first foothills. Specimens have been taken at an altitude of fully 8,000 feet. This insect doubtless causes heavy losses on the native pasture lands of the State.

June 29, 1901, a single pair of adults and many young were found in the foothills west of Ft. Collins; June 6th, 1902, in the some locality only young nymphs could be found; at Greeley, June 23, 1902, several adults were seen. (Ball.) Our latest captures of this species at Ft. Collins were made Sept. 5, 1901.

Specimens have been taken at the following places: Ft. Collins, Laporte, Dutch George's, Livermore, Westlake, Windsor, Greeley, Merino, Wray, Julesburg, Snyder, Boulder, Denver, Rockyford, Las Animas, Holly, Lamar, Alder, Dunkley and Steamboat Springs.

CORDILLACRIS Rehn.

affinis Morse. A single male answering to the structural characters given for this species, but having the dark stripe of the hind femora solid, was taken by Mr. S. A. Johnson at Hayden, July 29th. The hind tibiæ are very pale yellowish tinged with dusky and not at all red.

cinerea Brun. What I have placed under this name seems to be a light colored form of *occipitalis*, and it occurs over about the same area. Perhaps my specimens are not true *cinerea*, but if so, we have not taken this species in the State.

crenulata Brun. Generally distributed on dry grassy areas east of the Continental Divide to 8,000 feet altitude and also occurring over some of the western slope. It seems to be a grass feeder. The earliest that adults have been seen at Ft. Collins is June 26, 1901. (Ball.) They continue until the middle of September.

Specimens taken at Ft.Collins, Laporte,Windsor,Greeley, LaSalle, Wray, Boulder, Denver, LaFayette, Colorado Springs, Pueblo, Rockyford, LaJunta, Lamar, Las Animas, Trinidad, Ridgway, Antonito, Durango and Grand Junction.

occipitalis Thom. The notes for the preceding species may be repeated for this. In addition to the above localities we can add Dolores, Salida, Golden,Virginia Dale, Timnath, Ft. Morgan, Julesburg, Merino, Trinidad, Alamosa, Antonito and Durango.

Specimens from Trinidad, Alamosa, Antonito and Durango are darker in color and the elytra are longitudinally striped with dark fuscous with or without light yellow spots, but I do not take this form to be specifically distinct from the specimens from other parts of the State as there is considerable inter-gradation.

PHLIBOSTROMA Scudder.

quadrimaculatum Thom. A very common species feeding upon prairie grasses, particularly on the plains of the northeastern portion of Colorado. The species occurs in the foothills at an altitude of about 8,000 feet. It varies much in size and color, and in wing-length. This is one of our most destructive species to prairie grasses.

Specimens taken at Ft. Collins, Laporte, Dutch George's, Virginia Dale, Livermore, Windsor, Greeley, La Salle, Snyder, Sterling, Lafayette, Denver, Golden, Boulder, Pinewood, Pueblo, Colorado Springs, Rockyford, Holly and Buena Vista.

Adults taken at Ft. Collins from the 24th of June, 1901, until the 12th of October, 1898. Fully developed eggs found in females July 27th, 1901. (Ball.)

ORPHULELLA Giglio-Tos.

pelidna Burm. Thomas in writing of this species has said "Burmeister's description is so meager that it is doubtful whether it will ever be recognized with satisfactory certainty." What

I am calling this species is common in the northern plains portion of the State upon grassy areas and we have taken it in the foothills to an altitude of 5,500 feet. The males measure from 15 to 18 mm. and the females between 18 and 21 mm. in length. On going south this form gives way to a larger and longer winged form that I am calling *pratorum.* Scudd.

The specimens have been taken at Ft. Collins, Laporte, Windsor and Greeley. Adults have been taken as early as July 22, and as late as September 17th.

pratorum Scudd. What I am calling this species is abundant in the northern portion of the State east of the foothills and is also common in the southern portion. The males range between 18 and 20 mm. and the females between 21 and 24 mm. in length.

The specimens in the College collections have been taken at the following points: Ft. Collins, Greeley, Sterling, Snyder, Pueblo, Rockyford, Lamar and Holly in Colorado, and Stratton in Nebraska. See *Orphulella pelidna.*

salina Scudd. This low-ground species has been taken by us upon the west slope only in the vicinity of Delta and Grand Junction from July 7 to Sept. 23. On Sept. 17th, 1903, it was noted as the most abundant grasshopper on salt-grass, *Distichlis maratima*, growing through a heavy deposit of alkali on low ground near Delta. (Gillette.)

CHLŒALTIS Harris.

conspersa Harr. We have taken this species on five different dates at altitudes from 5,500 to 6,000 feet in the foothills west of Ft. Collins. The captures have all been from a single canon known as Horse-tooth Gulch and between July 10th and Aug. 12th. A single female was also taken in the foothills near Boulder July 23rd, 1901.

The females vary between 22 mm. and 24 mm. in length and their elytra vary between 8 mm. and 10 mm. in length. The males are from 18.5 mm. to 21 mm. in length and their elytra are from 9.5 mm. to 12.5 mm. long. In three of the males the entire sides of the pronotum to the lateral carinæ are black. In two others the lower portion is brown. The females lack the black dash upon the upper posterior angles of the sides of the pronotum. There are other reasons, particularly in the elytral venation of the males, for thinking that this Colorado form may be a new species.

STENOBOTHRUS Fischer.

curtipennis Harr. A common species on native grasses along the mountains and foothills of the State and occurring in smaller numbers across the plains of the northern portion. We have found it most abundant at altitudes of 8,000 to 9,000 feet. We have taken adults as early as June 26th in the foothills near Ft. Collins and as late as Sept. 30th in the same place. We have taken no females with elytra long enough to reach to the tip of the abdomen. With the males, however, the wings just attain the tip of the abdomen.

Specimens taken at Ft. Collins, Laporte, Dutch George's, Home, Sterling, Orchard, Merino, Greeley, Ward, Salida, Gunnison, Antonito, Lizzard Head, Alder, Cameron Pass and Walden.

PLATYBOTHRUS Scudder.

brunneus Thom. Both sexes taken in and near Estes Park, Aug. 11 to 13, 1903, sweeping native grasses between altitudes of 7,000 and 8,500 feet.

GOMPHOCERUS Thunberg.

clavatus Thom. This is preeminently a high-altitude species, though it occurs down to an altitude of something less than 5,000 feet, and has been taken by us along the Cache la Poudre river seven miles from the foothills. It occurs in large numbers on grassy areas above timberline. We have recorded it abundant on Mt. Ouray (near Marshall Pass) at 12,500 feet altitude, Aug. 27th, 1899.

In the foothills near Ft. Collins we have taken adults as early as June 17th, and on Marshall Pass as late as Oct. 7th. In the lower altitudes the species is not abundant.

We have taken specimens at Ft. Collins, Laporte, Dutch George's, Livermore, Westlake, Stove Prairie, Little Beaver, Home, Pueblo, Ward, Pike's Peak at 12,000 feet (Cockerell), Marshall Pass (on Mt. Ouray), and Cerro Summit.

The Colorado specimens are larger than Thomas' type, females measuring between 18 and 22 millimeters in length, with elytra 4.5 mm. to 8 mm. long, and males measuring between 15.5 mm. and 18 mm. in length.

It seems strange that the type of this species should have been recorded as taken in Kansas. Probably this is an error.

BOOPEDON Thomas.

nubilum Say. A rather common species along the Arkansas valley from Pueblo down, on moist ground where grasses grow. A few specimens have been taken from wheat and corn fields.

Outside of the Arkansas valley a specimen was taken at Wray (Ball). We have taken this species at Pueblo, Nepesta, Rockyford, Las Animas, Lamar and Wray.

All the males are black with hind tibiæ more or less red and with elytra nearly attaining the tip of the abdomen. In length they vary between 20 mm. and 27 mm. (52 specimens). Out of 30 females, 26 are dusky and greenish, marked with yellow, and four are black. They vary in length between 31 mm. and 44 mm., and, with one exception, the wings are short, about 12 mm. long. The single long-winged female has elytra surpassing the tip of the abdomen.

flavofasciatum Thos. Probably the light-colored form of the preceding species.

STIRAPLEURA Scudder.

decussata Scudd. Occurs across the plains and in the mountains to an altitude of 8,000 feet. Quite abundant in the vicinity of Ft. Collins. Occurs commonly in open grassy areas; food-plants not known.

Taken at Ft. Collins, Laporte, North Park, Denver, Colorado Springs, Pueblo, Rockyford, Lamar, Canon City, Trinidad, Antonito, Gunnison, Claremont, Elbert and Dunkley.

AGENOTETTIX McNeill.

deorum Scudd. What I take to be typical examples of this species in the collection are from Colorado Springs (Cockerell), Pueblo and Boulder, though others nearly as typical come from Rockyford, Ft. Collins and other points. This species seems to me to grade imperceptably into *scudderi*.

occidentalis Brun. (See discription following this article).

A west slope species, the specimens in the College collection coming from Antonito, Durango, Grand Junction, Glenwood Springs and Delta. Dates—Aug. 5th to Sept. 23rd.

scudderi Brun. A common species upon the plains near the foothills, particularly in the northern portion of the State. It extends to the eastern border of Colorado and to an altitude of 6,000 feet at least in the foothills. Adults begin to appear at Ft. Collins about June 20th and we have taken them as late as Sept. 28th. Adults were mating freely July 30th, 1902. (Ball.)

Specimens taken at Ft. Collins, Laporte, Dutch George's, Livermore, Greeley, Ft. Morgan, Snyder, Merino, Wray, Sterling, Julesburg, Boulder, Palmer Lake, Pueblo, Rockyford, Las Animas and Lamar. This species seems to me to be a unicolorous variety of *deorum*.

AULOCARA Scudder

elliotti Thom. This is also a very abundant species over the grass-covered plains of the eastern portion of the State, and occurs upon open grassy areas in the mountains to an altitude of 8000 feet. Adults appear in the vicinity of Ft. Collins about the middle of June and the sexes have been taken *in coitu* as early as July 2.

The 75 females in the collection vary in length between 21 mm. and 27 mm. and their elytra between 16 mm. and 18 mm. The males vary between 17 mm. and 20 mm. and their elytra between 11 mm. and 17 mm.

There is a wide variation in the colors. The common one is a dingy brown, slightly tinged with rufous, with more or less numerous brown spots, particularly upon the elytra. Occasional specimens are deep ferruginous in color with or without the fuscous spots upon the elytra and with the posterior portion of the dorsum of the pronotum deeply infuscated. Specimens from the higher altitudes (Buena Vista, Antonito and Gunnison) are smaller and are of a dark slate color with markings very inconspicuous.

Our specimens came from the following places: Ft. Collins, Laporte, Pike's Peak at 9000 feet (Cockerell), Dutch George's, Livermore, Sterling, Boulder, Lafayette, Va. Dale, Nepesta, Rockyford, Lamar, Trinidad, Canon City, Buena Vista, Antonito, Durango and Dunkley.

femoratum Scudd. A very abundant species near the foothills in northern Colorado. It occurs among the native grasses which probably serve as its food plants. It occurs entirely across the plains to the eastward but we have not found it occuring far back in the foothills nor upon the western slope. On July 16, 1902, adults were just beginning to appear in the foothills west of Fort Collins (Ball). In 1901 a few males were found in the same locality June 29, and on July 26th of this year Mr. Ball found females containing fully developed eggs. Occasional specimens have been observed at Fort Collins as late as Sept. 30, (1902).

This species has been collected at Ft. Collins, Laporte, Dutch George's, Windsor, Greeley, Ft. Morgan, Boulder, Rockyford, Las Animas, Lamar and Holly.

An examination of the 74 females and 52 males in the collection shows that the former vary between 19 and 25 mm. and their elytra between 12 mm. and 19 mm. in length, and that the latter vary between 14 mm. and 17 mm. and their elytra between

7 mm. and 12 mm. in length. The smaller size, shorter wing, conspicuous black bands upon the hind femora, and absence of the lower ridge for the inclosure of the frontal fovea easily separate this species from *elliotti*. In general appearance, the females of the two species are very similar.

rufum Scudd. We have found this species fairly common in the valleys of the Arkansas and the Rio Grande rivers and also at an altitude of about 8000 feet at Gunnison. We have also taken it upon the plains at Greeley and at LaSalle but not at Ft. Collins. The captures have been between June 24 (Greeley) and Aug. 11 (Denver).

Taken at Greeley, LaSalle, Denver, Pueblo, Nepesta, Rockyford, Lamar, Antonito and Gunnison.

This species also varies greatly in color. There are colors from light to dark slate through various shades of ferruginous. In some the elytra are conspicuously spotted with brown while in others the maculation is almost entirely absent. The posterior margin of the dorsum of the pronotum is usually darkened so as to be in sharp contrast to the lighter color of the elytra.

ARPHIA Stal.

frigida Scudd. We have taken this species at altitudes ranging between 5500 feet in Rist Canon near Ft. Collins and 12,000 feet on Marshall Pass.

This yellow-winged species has also been taken at Westlake, Little Beaver, North Park, Glendevy and Home. It seems to be distinctly a mountain species. We have not taken it outside of the foothills.

*__pseudonietana__ Thom. This large species with bright red under wings heavily bordered with black is quite abundant in northern Colorado and especially along the eastern foothills in the most barren places. It so imitates the ground upon which it rests that it can hardly be seen until it moves. It occurs to the New Mexico line in the southern part of the State. Our specimens come from the following points: Ft. Collins, Laporte, Dutch George's, Livermore, Sterling, Home, Windsor, Greeley, Orchard, Merino, Pinewood, Denver, Boulder, Palmer Lake, Colorado Springs, Pueblo, Rockyford, Las Animas, and Lamar.

The earliest capture was at Lamar, May 7, 1892, and the latest at Palmer Lake, Oct. 9th, 1898.

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*I am following A. N. Caudell in calling this species *pseudonietana* Thomas, instead of *tenebrosa* Scudder.

teporata Scudd. This species, which may be only a red-winged variety of *frigida*, is very common upon the plains in the vicinity of the foothills in northern Colorado. Our dates of capture range between March 31 and July 12 (Ft. Collins).

Our specimens have been taken at the following points within the State: Ft. Collins, Laporte, Greeley, Pueblo, and a single specimen from Silverton which may be a different species. We also have a pair of what seem identical with this form from Dunkley.

CHORTOPHAGA Saussure.

viridifasciata DeGeer. A common species in northern Colorado in the vicinity of Ft. Collins and occuring a short distance in the foothills. Adults have been taken as early as Apr. 23, and as late as July 2. The species winters as a nymph. The males (17) in the college collection are all brown. Out of the 25 females, 11 have the sides of the elytra and pronotum decidedly brown. Our specimens all came from the plains and foothills near Ft. Collins.

ENCOPTOLOPHUS Scudder.

coloradensis Bruner. See description in article following this.

costalis Scudd. Not uncommon near the foothills in the vicinity of Ft. Collins, also occuring some distance within the hills. Our specimens came mostly from near Ft. Collins, a few are from Greeley and one from Antonito.

CAMNULA Stal.

pellucida Scudd. A common species in open areas throughout the mountainous portions of the State. We have not taken it east of the foothills. More than 100 specimens in the College collection were taken at the following points: Home, North Park, Va. Dale, Dutch George's, Little Beaver, Pike's Peak at 10,000 ft. (Cockerell), Walden, Westlake, Sterling, Livermore, Stove Prairie, Cameron Pass, Leadville, Marshall Pass, Salida, Ward, Estes Park, Gunnison, Grand Junction, Rico, Hamilton, Steamboat Springs, Dolores, and Glenwood Springs. From outside the State, we have taken this species at Cheyenne, Wyo., and at Chama, N. M.

HIPPISCUS Saussure.

conspicuus Scudd. A fairly common species over the plains of the eastern portion of the State and in the lower altitudes through the mountains of the southern portion. Specimens in the collection are from Ft. Collins, Snyder, Sterling, Lamar, Pueblo, Trinidad, Antonito, and Gunnison.

The dates of capture range between May 9th and August 28 at Ft. Collins.

montanus Thom. Specimens determined for us by Prof. Bruner as this species were taken by Prof. E. D. Ball at Lamar, Colo., on three different dates, June 17, July 10, and July 18; and at Wray, Colo., July 13. It is one of the very largest and is the lightest colored species we have taken. The largest females measure 48 mm. in length. The hind femora and tibiæ beneath and on the inner sides are bright coral red and the metazone of the pronotum is long and acute angled posteriorly.

neglectus Thom. This seems to be strictly a mountain species. A single specimen has been taken on the first line of foothills west of Fort Collins at an altitude of about 5,500 feet, and at about 6,500 feet it becomes fairly common. Over 80 specimens in the College collection came from the following points: Ft. Collins (foothills), Livermore, Va. Dale, Westlake, Dutch George's, Estes Park, Home, North Park, Pike's Peak, Alder, Gunnison, Dolores, Steamboat Springs and Walden. Dates range between June 16 and Aug. 29.

paradoxus Thom, One male from Antonito, Aug. 5, '00 (Ball,) is all we have taken of this species. Determined by Prof. Bruner.

variegatus Scudd. Two males and two females taken by Prof. E. D. Ball at Holly, Colo., Sept. 8, 1898.

zapotecus Sauss. A few specimens of this species have been taken from the following points: Ft. Collins (foothills), Livermore, Westlake, Palmer Lake, Steamboat Springs, Eddy and Dunkley.

LEPRUS. Saussure.

cyaneus Ckll. Occuring in the most barren situations across the southern portion of the State. Our specimens came from Nepesta, Pueblo, Trinidad, Delta and Grand Junction. Determined by Prof. Cockerell. The hind wings of all the specimens are deep blue bordered with black and correspond exactly to Cockerell's description (Ent. News, 1902, p. 305.) The closely allied species, *wheeleri*, we have not taken in the State.

DISSOSTEIRA Scudder.

carolina Linn. Generally distributed over the State up to an altitude of about 8,000 feet. Adults taken from July 8th (Palisades) to Sep. 25 (Pueblo). Locations of capture: Ft. Collins, Laporte, Va. Dale, Dutch George's, Greeley, Orchard, Boulder, Pueblo, LaJunta, Lamar, Holly, Alamosa, Durango, Mc-

Elmo, Antonito, Cortez, Grand Junction, Delta, Hotchkiss, Paonia, Glenwood Springs, and Estes Park.

longipennis Thom. A common species east of the foothills, particularly in the southern portion of the State where it extends west into the foothills. It is very rarely that a specimen is seen at Ft. Collins. It is a common insect at the electric lights in Denver and at Colo. Springs. The college specimens are from Fort Collins, Greeley, Snyder, Sterling, Ft. Morgan, Denver, Pueblo, Canon City, Rockyford, Las Animas, LaJunta, Lamar, and Holly.

SPHARAGEMON Scudd.

aequale Say. A fairly common species in eastern Colorado and extending a short distance into the foothills. Our specimens come from Ft. Collins, Ft. Morgan, Boulder, Colorado Springs, Rockyford and LaJunta. The dates of capture are from July 8th to Sep. 14th. Large females have a striking resemblance to *Hadrotettix trifasciatus*.

collare Scudd. Our specimens, few in number, have been taken at Ft. Collins, Greeley, Orchard and Pueblo. A few of the Ft. Collins specimens were taken a mile or two back in the foothills. The dates range between July 10th and Oct. 3d.

cristatum Scudd. We have but few captures of this species, coming mostly from the eastern and southern portions of the State. The localities are Ft. Collins, Wray, Pueblo, Rockyford, Lamar, and from Stratton in Nebraska.

humile Morse. This is one of the most common species in the northern and eastern portions of the State. According to our collections it extends into the mountains to an altitude of about 9,000 feet. The captures are from the following points: Ft. Collins (both plains and foothills), Livermore, Dutch George's, Sterling, Ft. Morgan, Snyder, Wray, Orchard, Denver, Pinewood and Buena Vista. The dates of capture range between July 8th (Ft. Collins) and Sep. 19th (Buena Vista). The specimens that I am referring to this species seem hardly to be specifically distinct from *æquale*.

pallidum Morse. Along with the typical light colored specimens belonging to this species as determined for me by Prof. Bruner and Prof. Morse I have included a number of darker color that seem in every other way to be identical. The specimens before me came from the following points: Ft. Collins, Laporte, Greeley, Julesburg, Orchard, Denver, Pueblo, LaJunta, Lamar, Rifle and Delta.

DEROTMEMA Scudder.

haydeni Thos. This is a very common species throughout the State up to an altitude of about 9,000 feet, Light colored specimens that seem to be the true *cupidineum* of Scudder seem to me to grade insensibly into true *haydeni*, so I am including all under this name. Mr. Caudell distinguished *cupidineum* by the narrower black band of the wings which does not seem to hold true in all the spread specimens I have examined.

The 100 and more specimens of the College collection come from the following localities: Ft. Collins, Laporte, Livermore, Dutch George's, Julesburg, Ft. Morgan, Orchard, Sterling, Greeley, LaSalle, Lafayette, Denver, Boulder, Palmer Lake, Colorado Springs, Glenwood Springs, Pueblo, Rockyford, Las Animas, LaJunta, Lamar, Trinidad, Canon City, Salida, Buena Vista, Rifle, Colorado Springs, Gunnison, Antonito, Durango, Dolores, Delta and Grand Junction.

MESTOBREGMA Scudder.

thomasi Caud. (*cinctum* Thos.) Eight specimens collected from the following points: Colo. Springs, Pueblo and Nepesta. Dates range from July 19th to Sep. 25th.

kiowa Thom. A very common species on native grasses over the State generally, occuring in the mountains up to an altitude of fully 10,000 feet. Caudell reports having taken this species on the summit of Pike's Peak. The College collection of over 200 specimens came from Ft. Collins, Livermore, Dutch George's, Va. Dale, Julesburg, Sterling, Merino, Wray, Greeley, Windsor, Boulder, Denver, Colo. Springs, Pueblo, Palmer Lake, Rockyford, Las Animas, Trinidad, Ridgway, Antonito, Durango, Gunnison, Alma, Rifle, Estes Park, Steamboat Springs, Dunkley, Hamilton and Hayden. Dates of capture July 2nd to Oct. 9th.

mexicanum Sauss. Our 30 specimens of this robust species came from Ft. Collins, Dutch George's, Palmer Lake, Pueblo and Trinidad. Dates, Aug. 13th to Oct. 9th.

plattei Thom. A rather common species over the plains of the eastern portion of the State and occuring in the lower regions of the eastern slope to an altitude of 8,000 feet. The College specimens are from Ft. Collins, Dutch George's, Sterling, Wray, Home, Pinewood, Boulder, Colo. Springs, Pueblo, Rockyford, Nepesta, Las Animas, Lamar, Trinidad and Antonito. The dates range between July 8th and Sep. 3.

pulchella Bruner. (Determined by Prof. Bruner). Our 30 specimens of this beautiful green and black species are in the collection

from Ft. Collins and Va. Dale and one from Kimball, Neb. Dates, July 17 to August 16.

METATOR.

pardalinus Sauss. This is a common species in the vicinity of Ft. Collins. The College specimens are from Ft. Collins, Va. Dale, Dutch George's, Sterling, Steamboat Springs and Boulder. Dates range between June 28th and Sep. 12th.

There are 14 females and 6 males with red wings, and 14 females and 16 males with yellow wings.

CONOZOA Saussure.

gracilis Thos. The 55 specimens of this species in the College collection are all from the mountains except a specimen from Greeley and one from Pueblo. The localities of the captures are Greeley, North Park, Pueblo, Alder, Alamosa, Durango, Cortez, Dolores, Gunnison, Rifle, Paonia, Grand Junction, Steamboat Springs, Walden, Maybell, Hamilton, Glendevy, Lay, Dunkley and Craig.

TRIMEROTROPIS Stal.

azurescens Brun. A few specimens of this blue-winged species have been taken at Rifle, Paonia, Delta, Steamboat Springs and Hamilton, on the most barren hill-sides. July 25th to Sep. 23d.

agrestis McNeill. Specimens of this species as determined for me by Prof. Bruner come from Julesburg, Orchard, Greeley, Rockyford, LaJunta and Lamar.

bruneri McNeill. This is a common species on the northern plains of the State. In general appearance and markings it is wonderfully like *Hadrotettix trifasciatus*. The females are about the size of the males of that species. Specimens in the College collection are from Ft. Collins, Greeley, Ft. Morgan, Sterling, Pueblo, LaJunta and Antonito.

cincta Thom. There are 36 females and 59 males of this species in the collection and all came from the mountains or foothills of the State. Without exception the hind tibiæ are bluish or yellowish with a dusky patch a little beneath the knees in just the position to meet the black spot in the sulcus of the under surface of the femur. There are several specimens marked Ft. Collins in the collection but all came from Horse-Tooth mountain, a high foothill about 8 miles south-west of town. Our specimens have been taken at altitudes ranging between 6,000 and 10,000 feet and from both slopes.

citrina Scudd. A common and one of the very largest species that we have taken. I am including under this name forms that

seem to go well under *laticincta* and *latifasciata* but for which I am unable to find specific characters different from what I am calling *citrini*. Our specimens have been taken at the following places: Ft. Collins, Greeley, Va. Dale, Dutch George's, Ft. Morgan, Livermore, Pueblo, Rockyford, LaJunta, Lamar, Dolores and Durango. June 16 (Rockyford) to Oct. 6 (Ft. Collins.)

inconspicua Bruner. (See description in article following this).

monticola Sauss. A common species along the eastern foothills and extending across the plains in the northern portion of the State. It also occurs in the mountains of the central portion of the State to an altitude of 9,000 feet. Specimens taken at Ft. Collins, Livermore, Dutch George's, Va. Dale, Estes Park, North Park, Greeley, LaSalle, Colo. Springs, Ft. Morgan, Palmer Lake, Trinidad, Alder, Canon City, Buena Vista, and from Tie-Siding in Wyoming. Dates of capture, June 18 (Palmer Lake) to Sep. 18 (Palmer Lake).

montana McNeill. Five specimens of this species came from Durango, Grand Junction and Delta. July 28th to Sep. 23d. (Determined by Prof. Bruner and by Prof. Morse).

obscura Scudd. A few examples of this species all from mountainous districts: Palmer Lake, Salida, Antonito, Silverton (12,-000 ft.), Pike's Peak at 11,000 ft. (Cockerell), Steamboat Springs, Pagoda, Hamilton, Hebron and Lay.

vinculata Scudd. A common species across the southern portion of the State and occuring as far north, at least, as Ft. Collins. The localities of our captures are: Ft. Collins, Greeley, Pueblo, Colo. Springs, LaJunta, Nepesta, Lamar, Durango, Cortez, Dolores, Antonito, Alamosa, Palisades, Delta, Steamboat Springs, Craig, Maybell and Hamilton. Dates of capture are between June 15th (Pueblo) and Oct. 8th (Salida).

In this lot are a few specimens that I kept separate for a time as *similis*, but as the number of specimens increased the two forms seemed to run together. (Since writing the above the examples supposed to be *similis* have been determined for me by Prof. Morse as a form of *vinculata*).

CIRCOTETTIX Scudder.

carlinianus Thom. The specimens in the College collection are mostly from the vicinity of Ft. Collins. Other localities of capture are: Livermore, North Park, Dunkley, Palmer Lake, Colo. Springs, Durango, Grand Junction and Gunnison. Dates, June 26th to Oct. 4th at Ft. Collins.

suffusus Scudd. This very dark slender species we have taken in the foothills only, chiefly of the western slope, and in altitudes ranging between 7,000 and 8,000 feet. The males are very noisy with their wings. Rather common. Points of capture: Walden, Steamboat Springs, Dunkley, Estes Park, Palmer Lake, Durango, Hamilton and Pagoda.

undulatus Thom. Our examples of this species are from Ft. Collins, Dutch George's, Wray, Pueblo, Hague's Peak, Manitou, and Rifle; July 13th to Sep. 10th.

verruculatus Kirb. A mountain species which we have found more common in the middle and southern portions of the State. Our specimens are from Ft. Collins (foothills), Estes Park, Golden, Ward, Palmer Lake, Salida, Marshall Pass, Pike's Peak, Buena Vista, Paonia, Delta, Durango, Dolores, Rico, Steamboat Springs, Pagoda, Dunkley and Hamilton. Dates of capture, July 13th (Palmer Lake) to Oct. 8th (Salida).

HADROTETTIX Scudder.

trifasciatus Say. A common species over the native grass lands of the eastern portion of the State and extending some distance within the foothills. Some of the College specimens came from fully 8,000 feet altitude. Localities: Ft. Collins, Dutch George's, Livermore, Pinewood, Greeley, Wray, LaSalle, Sterling, Golden, Pueblo, Canon City, Rockyford, LaJunta, Lamar, Holly, Antonito and Salida. Dates, July 10th to Oct. 10th (Ft. Collins).

PARAPOMALA Scudder.

cylindrica Brun. This species probably occurs over the greater portion of the eastern plains of the State and in the lower foothills, where blue-grass, *Agropyrum glaucum* grows, which seems to be the chief food-plant. Localities of capture: Ft. Collins, (plains and foot-hills), Windsor, Orchard, Snyder, Julesburg, LaSalle, Rockyford, Las Animas and Lamar. Adults June 16th to Sep. 14th at Rockyford. We also have specimens from Stratton, Neb. (Ball).

Both green and brown forms occur throughout the range. I see no way to distinguish this species from *wyomingensis* Thos.

BRACHYSTOLA Scudder.

magna Gir. This very large species, commonly known as the "lubber" is quite common over the eastern plains to the foothills. It also occurs some little distance inside the hills in open grassy areas. We have noted it feeding upon American laurel, *Kalmia glauca*, and upon groundsel, *Senecio* sp. (Ball). The

males in the collection measure between 43 mm. and 61 mm., and the females between 45 mm. and 61 mm. in length.

The earliest we have found adults at Ft. Collins was July 10, 1901, and then only a single specimen could be found. On the 22d of the month adults were common and mating had begun. On Aug 1st of the same year some had begun to lay eggs and on Sep. 5th adults were common and several pairs were seen *in coitu* (Ball). Egg-laying begins about Aug. 1st.

In the males of this species the short wings are approximate or even overlapping on the back while in the females they are always widely separated.

SCHISTOCERCA Stal.

albolineata Thomas. What I am considering as this species are very closely related to the preceding, the only striking difference being the coral red hind tibiæ. There are specimens from Ft. Collins, Windsor, Timnath, Greeley, Merino, Orchard, Sterling, Julesburg, Nepesta, Rockyford, Lamar, Holly, Glenwood Springs, Grand Junction, Delta and Durango in the collection. The examples from the last four places named lack the black spots on the hind margins of the abdominal segments and have the hind tibiæ lighter red in color. The elytra are not noticably darker bordering the yellow stripe and the notch in the subgenital plate of the male is U-shaped, being broader than deep. Specimens from Delta and Grand Junction were taken from willows and from apple and peach trees. When disturbed they would take wing and fly from tree to tree. It is very likely these belong to a different species than the specimens from the eastern slope.

lineata Thom. This species occurs entirely across the State from north to south, east of the mountains. It occurs along water courses and seems to be arboreal in habit.

The males vary between 30 mm. and 35 mm. in length to tip of abdomen, and between 36 mm. and 43 mm. to tips of elytra. The females vary between 35 mm. and 48 mm. to tip of abdomen and between 42 mm. and 57 mm. to the tips of the wings.

The species varies very much in coloration; some are very pale yellow, others are yellowish green, and still others are of a rusty yellow. All have the hind tibiæ black behind and yellow before.

The earliest we have taken adults at Ft. Collins was July 10, 1899. Specimens have been taken as late as Sep. 5th at the same place and as late as Sep. 14, 1898 at Rockyford.

Specimens have been taken at Ft. Collins, Windsor, Greeley, Merino, Julesburg, Orchard, Manitou, Nepesta, Rockyford, Lamar, Holly and Trinidad.

HYPOCHLORA Brunner.

alba Dodge. This is a common species over the plains region of Colorado where its food plants occur. The two species upon which it chiefly occurs are *Artemisia frigida* and *A. ludoviciana* (white sage). It is not readily seen among the leaves of these plants which it closely imitates in color. The colors vary from a pale yellowish green to a rusty brown.

A large number of specimens in the College collection vary between 15 mm. and 19 mm. in length in the males, and between 21 mm. and 25 mm. in length in the females. The short pointed elytra measure between 4 mm. and 5 mm. in length in the males and between 5 mm. and 6½ mm. in the females. So far as known this insect attacks no cultivated plant.

Adults have been taken as early as July 8, 1898, at Ft. Collins and as late as Oct. 14th, 1901, at the same place. It has also been taken at Denver, Boulder and Julesburg, Colorado, and at Kimball, Nebraska.

CAMPYLACANTHA Scudder.

olivacea Scudd., seems to occur in the south-eastern portion of the State only. Several specimens were taken Sep. 8, 1898, at Holly, and others at Trinidad four days later, all by E. D. Ball.

This grasshopper is said to be partial to sunflower (*Helianthus*), and to lamb's quarter (*Chenopodium*), and Bruner suspects it of feeding upon beets also.

The 21 males in the College collection vary between 18 mm. and 22 mm. in length and the tegmina vary between 5 mm. and 7 mm. The 28 females vary between 22 mm. and 29 mm. in length and the tegmina vary between 5 mm. and 8 mm.

HESPEROTETTIX Scudder.

coloradensis Brun. (See description in article following this).

gillettei Brun. (See description in article following this). This seems to be a rare species in Colorado. After considerable searching I took five specimens from *Gutierrezia euthamiæ* at Glenwood Springs Sep. 15th, 1903. The collection also contains specimens from Delta, Grand Junction and Rifle, all points upon the west slope. July 13th to Sep. 16th.

pratensis Scudd. This is a fairly common, though not an abundant species over the plains and lower foothills of eastern Colorado. It seems to be of no economic importance as we have only recorded it feeding upon sunflower (*Helianthus*).

Our earliest were taken at Ft. Collins, July 6th, 1901, and our latest were taken at Greeley, Oct. 3, 1902. At Rockyford, July 16, 1901, this species was just becoming adult upon sunflowers. (Ball). At Ft. Collins on June 26 of the same year the nymphs were noted as being one-third grown (Ball).

We have made captures of this insect at the following points in the State: Ft. Collins, Livermore, Dutch George's, Home, Julesburg, Merino, Wray, Bald*Mt., Boulder, Golden, Palmer Lake, Colorado Springs, Lamar and Holly; also at Kimball and Stratton, Nebraska (Ball).

The greatest altitude at which we have taken this species is between 7,000 and 8,000 feet.

speciosus Scudd. This species occupies the same regions, practically as *pratensis*. It extends over the entire eastern portion of the State to the foothills and we have taken specimens at an elevation of somewhat over 6,000 feet in the hills.

The native food-plants of this species are sunflower (*Helianthus*) and a closely related composite, *Iva xanthifolia*. It is a much more abundant grasshopper than *pratensis*.

This species has been taken at the following places: Ft. Collins, Livermore, Dutch George's, Sterling, Julesburg, Orchard, Wray, Greeley, Merino, Pueblo, Rockyford, Las Animas, Nepesta, Lamar and Holly.

The 34 males in the collection vary between 20 mm. and 26 mm. in length, and the 66 females vary between 25 mm. and 34 mm. The wings are variable in length but in the great majority of cases they fall a little short of the tip of the abdomen in both sexes. Sometimes they are considerably shorter than the abdomen and occasionally they are slighlty longer. The males above mentioned have wings varying between 20 mm. and 26 mm. and the females have wings between 13 mm. and 24 mm. in length.

As this grasshopper feeds entirely upon native weeds it can not be considered of economic importance.

viridis Thom. This is one of the handsomest and most common of the plains species and occurs over all the eastern portion of the State up to the base of the foothills, where it is as abun-

*West of Loveland on Estes Park road.

dant as anywhere. It extends into the foothills for ten or fifteen miles in places and occurs as high as 7,000 feet in altitude, at least.

The native food plants are *Bigelovia* (rayless goldenrod) and *Gutierrezia euthamiæ.*

We have records of this species in the following places within the State: Ft. Collins, Dutch George's, Windsor, Greeley, Sterling, Wray, Boulder, Denver, Colo. Springs, Pueblo, Rockyford, Las Animas, Lamar, Nepesta and Holly.

Adults have been taken as early as July 2, 1901, at Ft. Collins and they were still abundant and mating freely at the foothills west of the town as late as Oct. 8, 1902 (Ball).

This species has not acquired, an appetite for cultivated plants and its native food-plants are not of economic value.

PODISMA Latreille.

dodgei Thom. This is distinctly a mountain species. We have taken it from just inside the first foothills at an altitude of 5,500 feet to 12,000 feet altitude upon the mountains. From 8,000 to 10,000 feet it is a rather abundant species. Food-plants unknown.

We have taken this species at the following Colorado points: Ft. Collins (foothills), Livermore, Dutch George's, Home, Ward, North Park, Lizard Head, Pike's Peak 12,000 feet (Cockerell) and Rico, as well as at several intermediate mountain points.

We have taken adults as early as June 12, 1900, near Ft. Collins and as late as Sep. 28th, 1898 in the same locality.

The 75 males in the collection vary between 14 mm. and 19 mm. in length and the 95 females between 21 mm. and 32 mm. The wings of the males vary between 4.5 mm. and 6.5 mm. and those of the females vary between 6 mm. and 8.5 mm.

stupefacta Scudd. Seventy-three males and 80 females of this species were taken by Mr. Charles Jones above timberline near Silverton, Colo., during August, 1903. He found this by far the most abundant grasshopper above 12,000 feet altitude in that vicinity. The hind tibiæ are universally red.

AEOLOPLUS Scudder.

chenopodii Brun. Taken at Grand Junction July 7, 1901, July 29, 1901, and Aug. 29, 1899; Palisades July 8, 1901, and Delta Sept. 23, 1901. The food-plant is a common species of *Atriplex* that is native upon the unirrigated ground in the neigh-

borhoods where the grasshoppers were taken. This species has been found fairly common about its food-plant. Upon being disturbed the hoppers jump in among the bunches of weeds and fall to the ground where they remain motionless for a time and are found with some difficulty as their color blends readily either with the food-plant or the ground.

The males vary between 14 mm. and 16 mm. and the females between 16 mm. and 22 mm. in length. The short elytra of the males vary little from 2½ mm. and those of the females vary little from 3½ mm. in length. Twenty-five males and 32 females examined.

minor Brun. (See description following this article).

plagosus Scudd. A few specimens of this species were taken at Delta, Colo., July 13, '01. They were fairly common on *Sarcobatus* sp. (greasewood), which was growing abundantly on seepage ground about the town. (Gillette.)

turnbulli Brun. This is a common Species over the plains region of Colorado east of the foothills. Its chief food-plants are species of *Atriplex* and Russian thistle. It has been seen feeding upon *Cleome* where its common food-plants were very scarce. *Atriplex expansa*, *A. canescens* and white sage, *Eurotia lanata*, have been specially noted as food plants of this insect.

We have taken this species at the following points in Colorado: Ft. Collins, Livermore, Julesburg, Sterling, Greeley, Ft. Morgan, Pueblo, Nepesta, Rockyford, Las Animas and Salida. The last named point is the only one any distance within the foothills where we have taken this species and only occasional specimens could be found there.

The Colorado specimens range rather larger in size than the types described by Prof. Bruner. The large number of specimens in the College collection measure as follows: Males between 17 mm. and 20 mm.; females between 17 mm. and 25 mm. The elytra vary somewhat in length but in nearly all cases they exceed the tip of the abdomen in both sexes. We have taken several females with short elytra, about 7 mm. in length, but have taken no short-winged males.

Adults have been taken from June 16 (Rockyford) to October 8 (Ft. Collins). The earliest that adults have been taken at Ft. Collins is June 26.

At the latest date mentioned, Oct. 8, many of the females still had immature ova of the second crop. (Ball.) Fourteen females were dissected Aug. 19th and only three seemed to have deposited their first batch of eggs. (Ball.)

This species, feeding almost exclusively upon weeds, can not be considered injurious at present and is not likely to become so unless it turns its attention to sugar beets which are closely related to the weeds upon which the hopper feeds.

MELANOPLUS Stal.

alpinus Brun. Taken between North Park and Cameron Pass, Aug. 20, 1899. (Ball.)

angustipennis Dodge. A single male answering the description of this species has been taken at Colorado Springs, Colo. It is indistinguishable from numerous specimens of *M. coccineipes* except for the blue hind tibiæ. It seems probable that *coccineipes* is a red-legged var. of *angustipennis*.

atlanis Riley. This is undoubtedly the most generally distributed species of locust in Colorado. It may almost be said to occur everywhere up to an altitude of 8,500 feet. Adults may be seen from about the 20th of June until after there have been several heavy frosts in the fall. This species is extremely variable in size and coloration. The lighter colored individuals have head, body and legs, except hind tibiæ, pale yellowish to rusty brown in color and even the elytra may partake of the color to a considerable extent. The latter may be conspicuously flecked with dusky spots or the dark spots may be entirely wanting. The light colored specimens are more prevalent in the lower warmer areas and early in the season and it is in the lower altitudes that the species attains its largest size. Specimens taken at 7,000 feet altitude and higher are nearly all small, dark-colored and without distinct markings. A common range in size between the small dark males of high altitudes and the larger ones of the eastern portion of the State is from 16.5 mm. to 26 mm., and the females range between 22 mm. and 27 mm. This insect does its injuries very largely to the native pastures though it is not averse to feeding upon various cultivated crops. It is certainly one of the most destructive grasshoppers to the native range pastures of the State.

At Ft. Collins, adults have been taken from June 22nd to November 11th. Many of the females taken on the latter date, 1902, still contained their second pod of eggs undeposited (Gillette). On July 26, 1901, a number of females were dissected at Ft. Collins and none of them had the first pod of eggs sufficiently matured for deposition (Ball). This species is evidently single brooded.

We have taken this species at the following points within the State: Ft. Collins, Laporte, Dutch George's, Liver-

more, Stove Prairie, North Park, Pike's Peak at 1,000 feet (Cockerell), Windsor, Greeley, Merino, Wray, Ft. Morgan Julesburg, Boulder, Lafayette, Denver, Palmer Lake, Canon City, Nepesta, Rockyford, Lamar, Holly, Trinidad, Colorado Springs, Salida, Buena Vista, Gunnison, Delta, Paonia, Grand Junction, Palisades, Durango and Steamboat Springs.

It seems probable that some of the reported occurrences of *Melanoplus spretus* should have been referred to this species.

bivittatus Say. This is undoubtedly the most injurious grasshopper in Colorado. It is doubtful if any insect causes heavier annual loss to the State. It is nearly, and perhaps quite as widely distributed as *femur-rubrum*. Its large size and great numbers and its appetite for cultivated plants of nearly every kind, make it very destructive. It is especially numerous in the alfalfa fields of the irrigated region near the foothills. Towards the eastern border of the State it is often out numbered by *differentialis*. It is also abundant in the alfalfa and grain fields of the western slope and sometimes defoliates fruit trees when orchards are not kept cultivated or when they are alongside of alfalfa or pasture land.

This species is capable of subsisting upon almost any cultivated crop. We have noted the following food plants: Alfalfa, red clover, grass, corn, wheat, oats, barley, fruit trees in general, cabbages, beets, potatoes and onions.

It has a strong tendency to climb tall plants and fence posts to rest for the night. The injuries are usually worst about the borders of fields.

There is comparatively little variation in the coloration of this species. The two yellow lines upon the elytra seem always to be present as a distinguishing characteristic; the head and pronotum are occasionally almost entirely pale yellow in color. In size and in wing-length this species varies widely. Males of long winged specimens vary between 21 mm. and 33 mm. in length and the females between 27 mm. and 41 mm. The majority of the specimens have elytra exceeding the tip of the abdomen but individuals with abbreviated wings are common and it is not very infrequent that they do not cover more that two-thirds of the abdomen. There are small males in the collection with elytra only 7.5 mm. long. As in *femur-rubrum*, the short winged individuals average smaller than those having long wings.

The earliest we have taken adults at Ft. Collins was June 12, 1900. June 21, 1901, a single male was found, and on

the 26th of the same month adult males were quite common (Ball). There is but one brood, as with all our Melanopli, but many of the eggs hatch late so that small nymphs are seen after many are adults. November 11, 1902, numerous females were seen at Ft. Collins and some of these had ova that were still immature (Gillette). Sept. 2, 1902, at Ft. Collins, occasional nymphs were seen and dissection of adult females showed that only about half of them had deposited the first pod of eggs. (Ball.)

We have recorded the species from the following places: Ft. Collins, Laporte, Livermore, Steamboat Springs, Eddy, Greeley, Sterling, Merino, Julesburg, Denver, Golden, Colorado Springs, Pueblo, Canon City, LaJunta, Rockyford, Lamar, Salida, Alder, Antonito, Delta, Grand Junction and Palmer Lake.

All the specimens in the collection have blue hind tibiæ and I do not remember certainly to have seen the form (or species) with red hind tibiæ in Colorado. It seems to me I have, but if so, the red-legged ones are only of occasional occurrence.

bowditchi Scudd. A common species in the southern portion of Colorado east of the foothills, and occurring in small numbers in the northern portion also. In the north it is largely replaced by a closely allied species *M. flavidus*. It is distinctively a plains species, and, so far as is known, confines its injuries to the native plants. We have found this species specially abundant along the Arkansas valley. Our dates of capture range between June 17th, 1900, at Lamar and Sept. 10th, 1898, in the same place (Ball). Food-plants unknown.

The males vary between 22 mm. and 25 mm. and the large females measure 30 mm. This species is readily separated from *flavidus* by its shorter antennæ(only 11 mm.long in the males) and by the presence of the black post-ocular band. It is also smaller and less robust as taken in Colorado. The fucula vary much in form at their tips. They may be truncate, cut diagonally, rounded, or slightly hooked, and two of these forms may occur on the same grasshopper.

Taken at the following places: Ft. Collins, LaSalle, Greeley, Timnath, Rockyford, Lamar and Colorado Springs, also at Kimball and Stratton in Nebraska. (Ball.)

coccineipes Scudd. This species occurs in moderate numbers over the entire plains region of Colorado and extends for some distance into the foothills. It varies in color from a dark

fuscous brown to almost a uniform and rather light rust-yellow. The lighter colored specimens occur mostly in the southern portion of the State. The post-ocular stripe varies from a broad and distinct black band to none. The subgenital plate is usually notched but in some specimens it is truncate. It seems quite probable to me that this species is nothing more than a form of *angustipennis* having red hind tibiæ.

The males we have taken vary between 19 mm. and 24 mm. in length. The females resemble allied species so closely that it is difficult or even impossible to distinguish them.

The only native food-plant we have recorded for this species is *Artemisia filifolia*. We have also taken it common on alfalfa and on young apple and plum trees.

Specimens have been taken at the following places: Ft. Collins (common), Laporte, Livermore, Dutch George's, Timnath, Greeley, Orchard, Julesburg, LaSalle, Boulder, Pueblo, Colorado Springs, Canon City, Lamar and Holly. Adult males and females have been taken at Ft. Collins as early as July 10, 1901, and as late as October 12, 1898.

comptus Scudd. We have a half dozen specimens of what seem to be *M. coccineipes* except that the furcula are nearly straight and but little diverging. So, while I should consider these as varieties of *coccineipes* I list them here because they seem to correspond better with the form that has been described as *comptus*. The specimens were all taken near Ft. Collins where we have done most of our collecting for *M. coccineipes*.

conspersus Scudd. This species occurs over the eastern plains and in the mountain parks of the eastern slope to an elevation of something over 8,000 feet. The species was found fairly common, for example, near Alder at an altitude of 8,500 feet on native grass land. It occurs most abundantly, however, on the grassy slopes of the foothills and upon the plains just outside the hills. While this locust has been found chiefly upon native grass-pasture land it has also been noted as feeding upon cabbages and alfalfa in moderate numbers. So the species is doubtless capable of adapting itself to a diet of cultivated plants if its supply of native food-plants should run short. It probably causes considerable damage where abundant upon native pasture land.

Our earliest capture of an adult of this species was at Greeley, July 13, 1898. But very few adults have been taken before Aug. 5th. Our latest capture was at Julesburg, Nov. 8, 1902.

We have taken specimens at the following points: Ft. Collins, Livermore, Windsor, Greeley, Julesburg, Boulder, Denver, Palmer Lake, Pueblo, Trinidad, Antonito, Alder, Salida and Buena Vista; and at altitudes varying between 4,500 and 8,500 feet. The high altitude specimens are smaller in size, darker in color and could easily be taken for a different species from the brownish testaceous form found in the lower altitudes.

The small males from high altitudes measure as small as 16 mm. in length while the largest from lower altitudes measure as high as 24 mm. The females measure between 18 mm. and 27 mm.

cuneatus Bruner. See *Melanoplus occidentalis.*

dawsoni Scudd. Our collections indicate that this species is confined to the foothills of the eastern slope of the mountains. It is not an abundant species but we have taken it from the border of the plains next the first foothills to an altitude of 8,000 feet. Specimens have been taken as far south as Palmer Lake. It is most common on the dry slopes of the lower foothills. The long winged form has not been taken.

Males vary in length between 14 mm. and 17 mm. and their elytra between 4.5 mm. and 6 mm. The females vary in length between 18 mm. and 20 mm. and their elytra between 5 mm. and 7 mm. Measurements upon 25 males and 31 females.

Specimens have been taken at Ft. Collins (at foothills), Dutch George's, Steamboat Springs, Pinewood, Boulder and Palmer Lake.

devastator Scudd. Two locusts taken at Steamboat Springs July 26th, 1891, were determined by Dr. Scudder as belonging to this species with a question mark attached. Altitude about 7,000 feet.

differentialis Uhl. This is an abundant and very destructive species in the lower altitudes of the State, especially where there is plenty of moisture. Except for the black markings of the posterior femora this species has no conspicuous markings but it varies much in color. In the warmer portions of the State the prevailing color is a light yellowish brown while in the higher and cooler portion the prevailing color is very much darker. In all places where the species occurs in the State there are occasional or frequent individuals that are black, except for yellow bands upon the legs, and sometimes light posterior lateral margins to the pronotum.

This locust is a very general feeder, particularly upon cultivated plants. Those we have noted are: alfalfa, corn, Kaffir corn, wheat, oats, leaves of apple, peach and plum and sugar beets.

The males taken vary between 27 mm. and 35 mm, and the females vary between 31 mm. and 42 mm. We have recorded the species from the following places: Ft. Collins, Windsor, Greeley, Merino, Julesburg, Loveland, Sterling, Laporte, Boulder, Pueblo, Colorado Springs, Canon City, Las-Animas, Rockyford, Lamar, Delta and Grand Junction. This species has been most abundant along the eastern portion of the State and at Grand Junction. We have not taken specimens above 5,500 feet altitude.

This species is rather late in maturing. A few adults were seen at Pueblo July 15th, 1901, and a few at Rockyford July 16th 1901 (Ball). The earliest adults at Ft.Collins were taken July 21, 1901. At Merino Aug. 8, 1902, females were not ready to oviposit. Females taken Nov. 11, 1902, still contained immature ova.

dimidipennis Brun. (See description following this article).

fasciatus Barnst. This species appears to be confined to the mountains and chiefly to high altitudes. Our specimens have come from twol ocations, Marshall Pass and Ward, at altitudes varying between 10,000 and 11,000 feet, except a single specimen taken in the foothills a few miles west of Ft. Collins at an altitude of 8,000 feet. I wonder if this mountain species can be identical with the *fasciatus* of the New England states. It is certainly a native of the high mountain ranges in Colorado where it occurs very sparingly.

The males vary between 15.5 mm. and 18 mm. in length and the females between 18 mm. and 21 mm.

All the specimens taken are short-winged, belonging to variety *curtus*.

femur-rubrum DeGeer. This is, next to *atlanis*, the most generally destributed of any species of *Melanoplus* in Colorado. Next to *bivittatus*, it is probably the most injurious species though *differentialis* is more injurious where it is most abundant. It occurs on both the eastern and the western slopes and in the mountains to an altitude of 8,000 feet. The species is extremely variable in color. The almost unicolorous fuscous-brown form that is common in the eastern states is not the prevailing form here. The abdomen and all of the under surface is usually distinctly yellow. The lower part of the

face, an area at the base of each antenna, a patch beneath and posterior to the compound eyes and a narrow line above each black post-ocular stripe, and often the posterior portion of the occiput,also,are yellow. Sometimes the entire head,except the compound eyes,the vertex and the post-ocular stripes,is yellow. The pronotum may be entirely dark fuscous with a broad black band on the prozona on either side, or the sides of the pronotum may be partly or entirely yellow outside of the black band of the prozona. The disk of the pronotum may be entirely yellow, or entirely rufous or it may be dark at the sides with a yellow or rufous median stripe of varying breadth. The femora may be yellowish shaded with dusky or they may be distinctly tinged with red. The hind femora may be dusky brown above with the lower half of the outer face yellow, or the outer face may be dusky brown throughout. In others the outer face is dusky brown with a yellow or even a reddish margin. In still others, and these are not uncommon, the dark parts of the femora are blue or bluish-green in color. In some the color is a deep steel blue. When these blue colors occur on the femora, the dark parts of head,thorax and elytra partake of the same tint. Those most highly colored with the blue often have the hind tibiæ tinted with the same color. These highly colored forms are among our handsomest grasshoppers and seem at first quite unlike the somber colored *femur-rubrum* as commonly described and seen in the east and yet there is so complete a gradation of forms between the extremes of coloration that I have not been able to separate out a distinct variety. It seems probable that these blue colored forms are what Dodge described as *plumbeus*. In fact he suggests that *plumbeus* may be only a local variety of *femur-rubrum*. At least I have been unable to find any characters that will hold to separate typical form of *plumbeus* from these highly colored forms of *femur-rubrum*.

The males we have taken vary between 17 mm. and 26 mm. in length and the females between 20 mm. and 26 mm. These are common variations. Occasionally a specimen is taken that seems abnormally small. This is especially true of occasional short-winged specimens that we have taken.

Short-winged form. We have taken specimens of a short-winged form of this species, mostly in shaded places. The elytra in these have been between 6 mm. and 7 mm. in length and reach a little beyond the middle of the abdomen. The males of this form have measured between 12 mm. and 16 mm. in length and the females about 18 mm. These were mostly taken by Prof. Ball.

The above is written up from 190 males and 100 females of the long-winged form and seven males and one female of the short-winged form.

The food-plants we have recorded for this species are: alfalfa, wheat, oats, corn, potatoes, beets, foliage of fruit trees and cabbage.

We have taken specimens at the following places: Ft. Collins, Laporte, Livermore, Virginia Dale, Windsor, Greeley, Merino, Ft. Morgan, Julesburg, Snyder, Orchard, Boulder, Denver, Palmer Lake, Pueblo, Canon City, Colorado Springs, LasAnimas, Rockyford, Lamar, Antonito, Salida, Gunnison, Ridgway, Delta, Paonia, Grand Junction, Palisades and Hayden.

The earliest that an adult has been found at Ft. Collins was June 26, 1901, (Ball). Ordinary years very few adults can be found before the 15th of July. Females taken Nov. 11, 1902, still contained immature ova.

flabellifer Scudd. See *occidentalis*.

flabellifer var. *brevipennis*. See description in following article.

flavidus Scudd. This is also a plains species and occurs sparingly in the southern portion of the State. It is abundant upon grass pastures along the foothills and upon the plains near Ft. Collins and has been taken feeding upon alfalfa, cabbages, leaves of plum and cherry trees and upon *Artemisia trifolia*, so that, whenever a food supply of native plants becomes scarce, this species is likely to become seriously injurious to cultivated crops.

This species is somewhat larger than *bowditchi*, the males ranging from 23 mm. to 26 mm. in length and the larger females measure as much as 32 mm. The antennæ of the males measure 14 mm. These dimensions are somewhat greater than those given for the types. We have taken adults at Ft. Collins from July 19th, 1902, till Sept. 19th, 1898.

Taken at the following points: Ft. Collins, Timnath, Greeley, Julesburg, and a single specimen at Lamar.

The furculæ of the male vary about the same as in *bowditchi*.

gillettei Scudd. Marshall Pass, Aug. 23, 1896 (Ac. 2260), and Aug. 27, 1899; Cameron Pass, Aug. 19 and 20,1899; Little Beaver, July 17, 1898.

This species has been found at high altitudes only. It was fairly common Aug. 27th on Marshall Pass between

11,000 and 12,000 feet altitude and was taken between 10,500 and 12,500 feet in altitude. Food-plants not known.

glaucipes Scudd. The collection contains 16 males and 22 females taken at Wray, Pueblo and Nepesta. The males vary between 17 and 20 mm., and the females between 20 and 27 mm. in length. See *Melanoplus simplex*.

infantilis Scudd. This is the smallest of our Melanopli and is a mountain and high plains species in this State. It seems to prefer grassy areas in exposed places and may commonly be found in the grassy mountain parks to an altitude of 8,000 feet at least. We have not seen the species much higher than this. The earliest adults at Ft. Collins were taken June 21st, 1901 (Ball). The latest we have taken the species is Oct. 12th, 1898.

Our specimens vary in size as follows: Males from 13 mm. to 19 mm. and females from 15 mm. to 21 mm.

We have taken specimens at Ft. Collins, Laporte, Livermore, Dunkley, Idlewild, Dutch George's, Virginia Dale, North Park, Denver, Palmer Lake, Pueblo, Alder, Estes Park, Durango and Gunnison, and at Kimball, Neb. It doubtless occurs east across the plains of the northern portion of the State.

It is hardly abundant enough to be considered an injurious species in Colorado.

kennicottii Scudd. Marshall Pass, Aug. 27, 1899; Durango, Aug. 7, 1899; Chama (N. M.), Aug. 8, 1899; Ward, Aug. 30, 1899. The lowest we have taken this species was at about 6,500 feet feet at Durango. At Chama,(N.M.),it was taken at the station, 7,863 feet, while at Ward and at Marshall Pass specimens were taken between 10,000 and 11,000 feet altitude. The species has not been found abundant anywhere.

lakinus Scudd. This is distinctly a plains species occurring all over the eastern portions of the State to the first foothills. It is common on ground covered by native grasses upon which it is supposed to feed though we have no positive evidence upon this point. It has been noted as feeding upon sugar beets and Russian thistle (Ball) and is usually common where tumble-weeds grow.

The species occurs in both long-and short-winged forms, the latter being by far, more common. Out of the 225 specimens in the College collection there are 12 macropterous males and 7 macropterous females.

The males vary in length between 14 mm. and 23 mm. and the females between 20 mm. and 26 mm. The elytra in the brachypterous forms vary between 4 mm. and 7 mm. in length in both sexes.

The macropterous form has been taken at Ft. Collins, Julesburg, Holly and Pueblo. The short-winged form has been taken at Ft. Collins, Julesburg, Wray, Sterling, Greeley, Colorado Springs, Pueblo, Canon City, Trinidad, Nepesta, Rockyford, LaJunta, Lamar and Holly.

This species varies widely in size and coloration in Colorado. In some the yellowish-brown prevails, even upon the elytra and pronotum; in others a decided greenish-yellow tint occurs on the same parts. At the other extreme there are those that are quite uniformly dark fuscous so that even the dark bands of the femora are hardly discernable. I am unable to find any constant characters separating this species from type specimens of *M. marculentus* from Mexico that are in the College collection.

luridus Dodge. An abundant species in northern Colorado east of the mountains. It seems to be most numerous in the vicinity of the foothills but does not extend far into the hills. The native food-plant is *Artemisia dracunculoides*. The nymphs with their genæ and sides of the pronotum (except a white median line on the latter) black, make conspicuous objects upon the stems of the food-plant. This species takes readily to some of the cultivated plants also. We have noted it feeding upon alfalfa, cabbages and leaves of plum and apple trees.

In size the males vary between 19 mm. and 21 mm. and the females between 20 mm. and 26 mm. Measurements from 61 males and 24 females.

Adult males were just beginning to appear July 22 at Ft. Collins in 1901 (Ball). They were abundant at Laporte Sep. 30, 1899, and specimens have been taken at Ft. Collins as late as Oct. 23, 1901.

This species has also been noted as feeding upon *Bigelovia* (Ball).

But few females were ready to lay eggs Sep. 8, 1902 (Ball).

We have taken this species at the following places: Ft. Collins (abundant upon dry ground), Laporte, Livermore, Ft. Morgan, Colorado Springs and Boulder.

minor Scudd. This is not an abundant species in Colorado but occurs in moderate numbers in the north-eastern portion over

the plains and for a considerable distance into the foothills. In fact it seems to prefer the slopes of the lower foothills and the plains near them. We have found it in places rather common on alfalfa and have frequently noted the species upon blue-grass (*Agropyrum glaucum*) and rush-grass (*Sporobolus cryptandrus*).

This is also the earliest of the *Melanopli* to mature. We have taken adults fairly common at the foothills near Ft. Collins on June 6th, 1902 (Ball). The latest that we have taken adults is Aug. 22, 1902 at Ft. Collins. This species occurs as far south as Pueblo, at least. It has been taken at the following points: Ft. Collins, Laporte, Livermore, Julesburg, Wray, Denver, Palmer Lake and Pueblo.

Our males vary in size between 17 mm. and 20 mm. and the females between 23 mm. and 26 mm.

Specimens have been taken at an altitude of 7,000 feet in the foothills.

monticola Brun. Three males and one female from Windy Point, Pike's Peak, at an altitude of about 12,000 feet, Sep. 17th, 1903 (Cockerell).

occidentalis Thom. This is a common and wide spread species. It seems to occur over the entire plains region from north to south. It is common among the lower foothills and upon grassy areas in the mountains to an altitude of 8,000 feet, at least. In the lower altitudes the males vary commonly between 19 mm. and 22 mm. in length and the females between 19 mm. and 24 mm. Specimens taken at higher altitudes, as at Dolores, Durango and Buena Vista, are decidedly smaller and darker in color. The males from these higher altitudes measure between 15 mm. and 18 mm. and the females between 17 mm. and 19 mm.

Adults have been taken as early as June 17th at Ft. Collins, 1898, and at Lamar 1900 (Ball). At Ft. Collins there is very little mating before the first of August and males have been taken as late as September 12th. There is but one brood. Food-plant not known.

We have taken this species at Ft. Collins, Livermore, McCoy, Dutch George's, Wray, Sterling, Snyder, Greeley, Denver, Pueblo, Rockyford, Las Animas, Lamar, Trinidad, Buena Vista, Durango, Gunnison, Antonito and Dolores, and at Kimball and Stratton in Nebraska.

The cerci of the males of this species vary considerably in form, the extremes resembling very closely, if they

are not identical, with the forms described for *flabellifer* and *cuneatus*, but with such imperceptible gradations that I have been unable to recognize either of these species as separate from *occidentalis* in our collections.

The pevailing form of *cercus* in Colorado is that shown in Plate X, Fig. 6 of Dr. Scudder's "Revision of the Melanopli," and this is the form that agrees with Thomas' original description of *occidentalis*.

packardii Scudd. This is a common species over all the eastern portion of the State to the foothills and it also occurs in the grassy glades and mountain parks of the eastern slope to an altitude of 8,000 feet or more. It would be difficult to say whether the species is more abundant on the level prairie or upon the sides and summits of the low hills. It seems to be everywhere on land covered with native grasses, but that the grasses are its food-plants is an inference. This species is not uncommon in alfalfa fields and has been noted by us as feeding upon cabbages. The species is so large and abundant it must do considerable damage to native pasture land.

Males were just beginning to mature at Ft. Collins, June 29, 1901, and occasional adults were noticed in the same locality Oct. 8, 1902. (Ball.) Our adults were taken at Greeley June 24, 1899.

The species varies in Colorado from a light rusty brown to a rather dark brown with more or less distinct lighter stripes on the lateral margins of the dorsum of the pronotum. In some of the darker specimens these lines are obsolete.

In length, the males vary between 23 mm. and 29 mm. and the females between 23 mm. and 33 mm. Among the 127 specimens in the College collection there are 33 males and 21 females with blue hind tibiæ and 36 males and 37 females with red hind tibiæ.

This grasshopper has been taken in the following localities in Colorado: Ft. Collins, Dutch George's, Livermore, Julesburg, Sterling, Orchard, Wray, Greeley, Windsor, Estes Park, Boulder, Lafayette, Denver, Palmer Lake, Pinewood, Durango, Rockyford, Lamar and Holly.

regalis Dodge. A few specimens of this species were all taken by Mr. Ball. One specimen from Ft. Collins, August 14, and specimens from Holly, Lamar and LasAnimas bearing dates July 18 and September 8. Specimens determined by Prof. Bruner.

This is one of the handsomest of our Melanopli and is very different from the species of *Aeoloplus* that has been supposed to be Dodge's *regalis*.

This species might easily be mistaken for *sanguineous* Bruner.

sanguinous Brun. (See description in article following this). A few specimens only and all from the south-eastern portion of the State. The localities are Holly, Lamar, Las Animas and Rockyford. Dates, July 17th to Sep. 14th (Ball). In general appearance closely resembling *regalis*.

simplex Scudd. Two males have been taken in the Arkansas Valley, one at Holly, Sep. 8, 1898, and one at Nepesta, Aug. 6, 1900 (Ball). The first measures 17 mm. and the second 19 mm. Tegmina of male from Holly 8 mm. and of the one from Nepesta 13 mm. The latter specimen has blue hind tibiæ and may belong to *glaucipes*, but aside from the longer elytra and the different colors of the tibiæ, and the difference in size, the two specimens appear to be identical. This species seems a very close relative of *glaucipes* but in general appearance, as we have them determined, *glaucipes* is more slender and with the male abdomen nearly straight, while in *simplex* the male abdomen is strongly upturned at the end.

spretus Uhl. I cannot help suspecting that some of the reported occurences of this species have been from specimens of *atlanis*. During thirteen years of collecting in Colorado, and we have done a large amount of it, we have not taken a single specimen of this locust. I do not think it can have any permanent breeding ground within this State at present.

tristis Bruner. See description in article following this.

yarrowi Thom. A single pair were taken at Grand Junction Aug. 28, 1894. This species looks very much like *M. flavidus* with hind tibiæ red, or like a light colored specimen of *M. femoratus* without the pale stripes and not so robust. Length of male 25 mm. and of female 35 mm.

PHŒTALIOTES Scudder.

nebrascensis Thom. Another common species on grass land on the eastern plains of the State. Its food-plant, so far as our observations have gone, is blue-grass (*Agropyrum glaucum*). This specicies is rather late in maturing. On July 16, 1902 at Ft. Collins many nymphs but no adults were observed upon *Agropyrum*. On July 30th the adults were common. On Aug. 1st, 1901 at the same place it was noted that there were many nymphs and a few adults upon blue-grass. The adults

were still common Sep. 25th, 1898, near Ft.Collins (notes by Ball).

The males in the collection vary between 19 mm. and 23 mm. in length and the females measure from 23 mm. to 29 mm. in length. The elytra of the short-winged males vary between 5 mm. and 6.5 mm in length and those of the females between 5.5 mm. and 7.5 mm. in length.

A few specimens of the long-winged form (*volucris*) have been taken at Ft. Collins and one specimen was taken at Lamar.

We have taken the species at the following places: Ft. Collins, Greeley, Julesburg, Merino, Pueblo, Colorado Springs, Rockyford, Lamar and Holly.

DACTYLOTUM Charpenter.

pictum Thom. A fairly common species on the plains of the eastern portion of the State and occuring on dry exposed areas for some distance within the foothills but not far. Its principle food-plant,according to Prof. Ball's notes,seems to be *Aster multiflora* though he has several times noted it feeding upon *Kalmia glauca* (American laurel). He has also seen it resting upon *Senecio Douglasi*, apparently as a food-plant, and we have found occasional specimens on alfalfa.

The bright coloration is very constant; males vary between 20 mm. and 24 mm. in length and the females between 29 mm. and 35 mm. The wings of the males vary between 4 mm. and 5 mm. and those of the females between 5 mm. and 6 mm. Taken at the following places: Ft. Collins, Laporte, Livermore, Wray, Pueblo, Rockyford, Lamar and Holly.

We have found the species abundant just outside the first foothills and have taken adults at Ft. Collins from July 26th to Sep. 30th.

Some New Colorado Orthoptera

BY LAWRENCE BRUNER.

Nemobius brevicaudus new species.

A medium sized, pale colored insect in which the female has an exceedingly short ovipositor, not much more than one-half as long as that of other species in which this member is described as greatly abbreviated. In general appearance perhaps most closely resembling *N. mormonius* Scudd. from Utah.

Pale testaceous with a few darker markings on head, pronotum and abdomen above. The pronotum a little narrower in front than behind, its surface sparsely adorned with rather stiff, not very long, dark colored bristles. Front and middle femora, as well as the front between the base of antennæ, likewise adorned with similar bristles. Tegmina half as long as abdomen, about as long as head and pronotum combined (♀), or nearly reaching its apex (♂) pale testaceous, without any definite darker markings. Ovipositor very short, straight, the apical half moderately coarsely toothed above, the extreme apex rather blunt. Anal stylets pale, slender, a little longer than hind tibiæ.. Antennæ rather long and slender, testaceous basally, darker beyond.

Length of body, ♂, 8 mm., ♀, 8.5 mm.; of hind femora, ♂, 5 mm., ♀, 5.5 mm., of ovipositor, 1.85 mm.

Habitat. 1 ♂, 1 ♀, Fort Collins, Colorado, October 4, 1901.

Ceuthophilus aridus new species.

Of a uniformly pale testaceous color,a trifle darker above than below, unadorned by darker mottlings, bands or blotches of any kind, a moderately slender insect with relatively smooth body and limbs. Eyes very dark brown or black, pyriform, the apex below. Front femora about one-fourth longer than pronotum, their front edge below provided with 1-2 very small spines in addition to a much longer preapical one, the lower posterior edge unarmed; anterior lower edge of middle pair armed with 3-4 and the posterior with 2-3 minute ones, the apex of the latter edge provided with an apical spine. Hind femora rather robust, without any decided genicular enlargments, a trifle over three times as long as greatest width, the apical half provided above with a number of dark raised points, and both the outer and inner lower carinæ furnished with numerous fine serrations, the sulcus rather narrow except near the apex. Hind tibiæ about one-sixth longer than femora, nearly straight and provided with four pairs of moderately strong gently diverging spines

in addition to the apical ones which are somewhat longer than the others; hind tarsi about one-third the length of the hind tibiæ, joint 2 twice as long as 3. Cerci rather slender, in length less than the greatest width of hind femora and abruptly bent downwards at about the middle.

Length of body, ♂, 12.25 mm., of pronotum, 3.45 mm., of fore femora, 4.2 mm., of hind femora. 9.65 mm., of hind tibiæ, 10.5 mm.

Habitat. A single ♂, November 17, at Grand Junction, Colorado.

On account of its uniform pale color this insect reminds one at first glance of all three of the following named species; viz., *C. alpinus* Scudd., *C. pallescens* Bruner, and *C. vinculatus* Scudd., from all of which, however, it differs in several important points as indicated in the description.

Ageneotettix occidentalis new species.

Very similar to both *A. scudderi* and *A. deorum*, but differing from both of these in its somewhat slenderer form and smaller size, as well as in the fewer (9) spines on the outer row of hind tibiæ, and in its normally somewhat abbreviated tegmina and wings.

Length of body, ♂, 10.5-13 mm., ♀, 15-18 mm.; of pronotum, ♂ 1.95-2.10 mm., ♀, 2-2.15 mm.; of tegmina, ♂, 7-9 mm., ♀, 9-10 mm.; of hind femora, ♂, 7.25-9 mm., ♀, 8.5-10 mm.

Habitat. Various localities in Colorado west of the main range, during the months of July, August and September (Collection Colorado Agricultural College).

Whether or not these are distinct, or only well marked geographical forms of a single rather variable species, is not certain now. However, the following brief synoptical table will show the main differences among these forms:

A[1]. Normally with somewhat abbreviated tegmina and wings in both sexes. Hind tibiæ nine spined in outer row.. *occidentalis* n. sp.

A[2]. Normally with tegmina and wings hardly ever shorter than abdomen. Hind tibiæ ten or eleven-spined in outer row.

- *B*[1]. Smaller, the tegmina and wings about equalling the abdomen in length even in ♂. Fastigium slightly acute-angled in male.......... *deorum* Scudd.
- *B*[2]. Larger, the tegmina and wings slightly surpassing tip of the abdomen in ♂. Fastigium right angled or even more obtuse in male as well as in female.......... *scudderi* Bruner.

Encoptolophus coloradensis new species.

Somewhat resembling *E. sordidus* in general form but differing from it in a number of respects. The chief of these variations are a lower median carina of the pronotum in which the two sections are about equal in height, glaucous instead of fuliginous hind tibiæ, and a prevailingly pale grayish testaceous color with decided dark markings on tegmina, hind femora and posterior half of pronotal disc.

Head unusually large and gross, quite distinctly broader than the front edge of the pronotum and higher than the general depth of the body; the vertex between the eyes about as wide as the shortest diameter of the latter, the scutellum broadly pyriform, rather shallow and provided in its posterior half with a well defined longitudinal carina which is continuous over the occiput to the front edge of the pronotum; lateral foveolæ small, triangular, scarcely sulcate; frontal costa rather prominent, the sides evenly diverging downwards, quite deeply sulcate in the vicinity of the ocellus, the bounding walls heavy; antennæ about reach-

ing the hind edge of the pronotum. Pronotum somewhat strangulate in advance of the principal sulcus, the lateral carinæ not much interrupted though bowed, fairly prominent; the median carina straight, of medium height, cut a little in advance of its middle; hind edge of the disk somewhat obtuse-angled. Tegmina and wings about equalling the abdomen in length, the apex of former broadly rounded. Hind femora normal, not quite reaching the tip of the abdomen.

General color pale grayish testaceous, the sides of pronotum obscurely banded with dull black or brown, the disk of pronotum with the X-shaped pale marking of *sordidus*, *costalis* and *parvus*. Tegmina crossed with four heavy dark bands and marked basally with irregular small blotches. Hind femora decidedly trifasciate with fuscous externally; hind tibiæ largely glaucous, the base pale. Sutures of abdomen narrowly black.

Length of body, ♂, 19 mm., ♀, 28 mm.; of antennæ, ♂, 7 mm., ♀, 8 mm.; of pronotum, ♂, 4 mm., ♀, 5 mm.; of tegmina, ♂, 17, ♀, 20; of hind femora, ♂, 11 mm., ♀, 14 mm.

Habitat. Fort Collins, Colorado, August 14, a single ♀ (C. P. Gillette); same locality, 1 ♂, and 1 ♀ (L. Bruner).

Trimerotropis inconspicua new species.

A trifle under the medium size for the *vinculata* group to which it belongs, and at once recognized by its generally light color and comparatively narrow, but well defined, posteriorly converging tegmina bars, together with the pale disk of pronotum.

Head of moderate size, the eyes a trifle prominent and semiglobose. Vertex longer than wide and provided with a well-defined longitudinal carina. Antennæ dark brown annulated with testaceous, nearly or quite as long as hind femora. Pronotum rather flat on disk but provided with a net-work of low, smooth ridges which gives its surface a granular appearance; the anterior lobes very little tumid and furnished with a median carina which is but little more prominent than that on the hind lobe; posterior edge of disk right-angled in both sexes. Tegmina extending nearly one-third (♂) or only about one-fifth (♀) of their length beyond the tip of abdomen, the veinlets on basal half or two-thirds very numerous and a trifle coarse, thereby giving to that portion of these members a sort of granular appearance. Hind femora moderately slender, not quite reaching (♀) or a little surpassing (♂) the tip of abdomen.

General color very light cinero-ferruginous, with the usual dark-brown or blackish markings of the group to which it belongs. In some specimens the anterior portion of pronotum both on sides and disk are marked with clusters of small black flecks, but in others this portion is entirely pale—being relieved only by the brownish dots which adorn the carinæ of vertex, front, cheeks, pronotum, etc. The pale ferruginous tint which pervades the whole insect is due chiefly to the color of the bottom of punctuations which are well scattered over its surface. While the bands on tegmina are not solid they are quite prominent and made up of clusters of dark dots or by the infuscation of certain veinlets. On the basal portion these bands are narrower than usual and show a decided tendency towards converging posteriorly, while the apical portion is nearly destitute of markings save for the infuscation here and there of a few veinlets. Wings with their disks very pale greenish-yellow, crossed about the middle by a narrow fuliginous band which sends its anterior spur nearly one-half way to the base, the apical portion beyond the band perfectly transparent. Hind femora with lower sulcus yellow or at least with two pale bands. Hind tibiæ, except on extreme base where they are dark-brown, pale greenish-yellow, a little infuscated beyond the subbasal pale annulus and apically. Front and middle legs with well marked dusky annulations.

Length of body, ♂, 17 mm., ♀, 24-26 mm.; of antennæ, ♂, 10 mm., ♀, 10.5 mm.; of pronotum, ♂, 4 mm., ♀, 5.5 mm.; of tegmina, ♂, 18.5 mm., ♀, 24-25 mm.; of hind femora, ♂, 10-10.5 mm., ♀, 10.5-12 mm.

Habitat. Paonia, Palisades, Rifle and Dolores, Colorado, during the months of July and August.

In the McNeill table of species of Trimerotropis this insect will fall into the *vinculata* group with *salina*, *similis pallidipennis* and *longicornis* (The latter a new species described by E. M. Walker in Can. Ent. xxxiv, 4). That portion of the table may therefore be modified as follows:

f^1. Lower sulcus of posterior femora light, with one preapical black band, or black, with two light bands, one preapical and one median, the latter not merely interrupting the black on the edges of the sulcus, but in the bottom as well.

g^1. Fuscous band in its usual position in the middle of the wing. Spur extending less than half way to the base.

h^1. General color light cinereo-ferruginous. The bands of tegmina well marked and rather strongly converging towards the posterior edge.......... *inconspicua* n. sp.

h^2. General color dark fuscous brown, permitting little contrast in the bands of tegmina, the latter not markedly conconverging towards posterior edge.

i^1. Metazona scarcely more than one and one-half times as long as prozona. Fuscous band variable.

j^1. Fuscous bands of wings very broad, occupying nearly one third the length of the wings, apical portion with only a few fuscous dots........*salina* McNeill.

j^2. Fuscous bands of wings narrower, occupying less than a fifth of the lenght of the wings, apical portion rather strongly infuscated.............. *longicornis* Walk.

i^2. Metazona twice as long as the prozona. Fuscous band rather narrow, occupying no more than a sixth or seventh of the length of the wings.............. *similis* Scudd.

g^2. Fuscous band entirely beyond the middle of the wing, making the length of the disk equal to the width. Fuscous spur extending more than half way to the base.......*pallidipennis* Burm.

f^2. Lower sulcus of the posterior femora black, with but one preapical light band ....*vinculata*, *huroniana*, *collaris*, *fratercula*, *saxatilis*, and *sordida*.

Aeoloplus minor new species.

A small, slender, short-winged insect with pinkish or light purplish hind tibiæ, in which the supraanal plate of male resembles quite closely that of the longer-winged *Ae. tenuipennis* Scudder, from Arizona.

Head a little longer than the front edge of pronotum, the occiput somewhat ascending; eyes only moderately prominent, the vertex between them a little narrower than the frontal costa between the antennæ and deeply sulcate to upper end of costa, in both sexes; the latter scarcely sulcate even at the ocellus; antennæ short and slender, scarcely reaching hind edge of pronotum in either sex. Pronotum with the anterior lobes about equal, the disk smooth and evenly rounded, without a perceptible median carina; hind lobe slightly expanding posteriorly, the the surface punctulate and with a slight median carina, the hind edge broadly angulate. Tegmina and wings abbreviated, rather narrow and evenly tapering, reaching from the middle to three-fourths the length of abdomen. Hind femora robust and furnished at base with a large downward projecting tooth, reaching beyond the tip of abdomen in both sexes. Apical segments of male abdomen only slightly enlarged, the last ventral segment ending in a short, blunt, upward projecting point; cerci nearly as long as supraanal plate,evenly tapering on basal three-fourths, equal beyond, the apical portion gently bent inwards; supraanal plate subtriangular, the sides sinuose and having the apex produced and

rounded, the surface practically as descibed for *Ac. tenuipennis.* Valves of ovipositor slender, short.

General color testaceous, varied with the usual brown markings, in some specimens with an olivaceous tinge, especialy on tegmina and hind femora. Sides of basal abdominal segments and about base of supraanal plate and cerci dark brown or piceous. Posterior femora with the usual dusky bands which are some shade of olive or brownish olive, the genicular lobes and base of tibiæ a little darker, the latter decidedly pinkish or pale lilac, in some specimens changing to glaucous apically.

Length of body, ♂, 12 to 14 mm., ♀, 14 to 15 mm.; of pronotum, ♂, 3.1 mm., ♀, 3.85 mm.; of antenæ, ♂, 6 mm., ♀, 5 mm.; of tegmina, ♂, 6-7.5 mm., ♀, 6.5-7.5 mm.; of hind femora, ♂, 6 mm., ♀, 8 mm.

Habitat. ♂s and ♀s, Delta, Colorado, July 13, 1901.

The annexed portion of Scudder's table will show the affinities of the present species:

*d*². Cerci of male tapering almost uniformly through the basal three-fourths, only the apical half or less equal.

*e*¹. Larger. The tegmina and wings almost as long as abdomen. Hind tibiæ pale glaucous..*plagosus* Scudd.

*e*². Smaller. Tegmina and wings from one-half to three-fourths as long as abdomen. Hind tibiæ pinkish or pale purplish. *minor* n. sp.

Hesperotettix Gillettei new species.

The distinguishing characters of the present species are the non-obscured transverse sulci of pronotum, the very narrow tegmina and bright salmon-colored anterior and middle, as well as the entire upper edge and pregenicular annulations of hind femora.

A bright grass-green locust with prominent white lines on thorax and along humeral angles of tegmina. In comparison with *Hesp. viridis* it is a somewhat slenderer insect of a more subdued and uniform color in which the pronotum is less expanded posteriorly and the tegmina and wings are decidedly narrower and show a variation in length from about one-half as long to a trifle exceeding that of the abdomen,a little longest in the males. It differs from its nearest ally, *Hesp. festivus*,in being of a much more uniformly cylindrical form and greenish color, in its more cylindrical pronotum and the heavier hind femora, the shorter and heavier cerci and the slightly more elevated and blunter apex of subanal plate of male abdomen.

Length of abdomen, ♂, 15 mm., ♀, 21 mm.; of pronotum, ♂, 3.5 mm., ♀, 5 mm.; of antennæ, ♂, 7.5 mm., ♀, 6.5 mm.; of tegmina, ♂, 6 to 11.5 mm., ♀, 7.5 to 16 mm.; of hind femora, ♂, 9 mm., ♀, 12 mm.

Habitat. Rifle, Colorado, July 25, ♂s and ♀s; Glenwood Springs, September 15; Delta, July 13 and Grand Junction, July 29, September 16.

Hesperotettix coloradensis new species.

A short-winged moderately robust insect which is quite closely related to *H. curtipennis*, but differing from it by its somewhat slenderer form, slenderer and shorter hind femora, the much shallower and less prominent transverse sulci of pronotum, the slenderer and longer valves of the ovipositor, and in lacking the pale border above dusky band on sides of pronotum. Otherwise the two forms are quite similar in general appearance.

Head small, eyes rather prominent; the vertex narrow, about as wide as basal (♀) or as second (♂) joint of antennæ, rather deeply sulcate in male, less so in female; frontal costa moderately broad, the sides nearly parallel, profoundly sulcate throughout. Antennæ with the joints somewhat depressed and heavier than usual in the male, in female nor-

mal. Pronotum subcylindrical, only gently widening behind, the anterior lobes smooth, only weakly punctate, and with ill-defined median carina; the hind lobe coarsely and rather closely punctate, its median carina quite evident, hind margin angulate. Tegmina lobate, lateral, their dorsal edges not touching. Hind femora slender, not quite reaching (♀) or gently surpassing (♂) the tip of abdomen. Apical portion of male abdomen slightly broadened, the extreme tip of last ventral segment gently raised above the level of apex; supraanal plate elongate, its sides upturned, the apex rounded and provided in middle with two rather coarse, blunt carinæ which begin near the base just in advance of the furculæ which are mere protuberances and meet a little before tip; cerci moderately long, about reaching the tip of supraanal plate, their apex attenuate and gently curved inward; valves of ovipositor slender, somewhat exserted.

General color grass-green varied with pale testaceous and dirty white. The sides of pronotum back of eyes streaked longitudinally with piceous bordered below by dirty white. Dorsum of thorax and abdomen with the usual light colored streak which frequently widens in the middle of anterior lobe of pronotum so as to form a sort of a diamond-shaped patch—a little interrupted just before reaching the hind edge. Hind femora internally and below testaceous, with scarcely any indication of the pregenicular ruddy annulation or tinge along upper edge.

Length of body, ♂, 16.5 mm., ♀, 24 mm.; of pronotum, ♂, 4 mm., ♀, 4.85 mm.; of antennæ, ♂ and ♀, 7 mm.; of hind femora, ♂, 9.5 mm., ♀, 10.5 mm.

Habitat. 1 ♂, Durango, Colorado, Aug. 7; 1 ♀, Dolores, Colo., Aug. 2. (Collection Colo. Agr. College).

With the addition of these two, and a third species from Florida, to those known to Scudder, we have his table of species considerably modified. . This modified table is as follows:

ANALYTICAL KEY TO THE SPECIES OF HESPEROTETTIX.

A[1]. Metazona of pronotum distinctly punctate on dorsum; prozona smooth, except sometimes feebly punctate on dorsum; nowhere rugulose.

b[1]. Pronotum highly and irregularly diversified in color, or else nearly devoid of markings of any kind, the dorsum nearly plane; tegmina in the diversified species marked with a white or pallid stripe on the division line between the discoidal and anal areas.

c[1]. Transverse sulci of pronotum distinctly marked in black; hind femora with a distinct preginicular annulation.

d[1]. Relatively slender-bodied, with slender femora; tegmina rarely as short as the body and then only in male; antennæ of male slender, distinctly longer than the head and pronotum together... .... *viridis* Thom.

d[2]. Relatively stout-bodied, with stout femora; tegmina surpassing the body only in the males and then but slightly; antennæ of male coarse, scarcely longer than the head of pronotum together... ..... *meridionalis* Scudd.

c[2]. Transverse sulci of pronotum not marked in strong colored contrast to surroundings.

d[1]. Tegmina not abbreviate, about as long as the abdomen. Hind femora without red pregenicular annulation or only faint signs of one.............. .....*festivus* Scudd.

d[2]. Tegmina one-half or even a trifle longer than abdomen. Hind femora with a decided pregenicular annulation.......... .... *gillettei* n. sp.

b^2. Pronotum diversified in color only by longitudinal stripes, the dorsum distinctly tectiform; tegmina without pale stripes (though they are occasionally indicated).

c^1. Tegmina lobiform, little or no longer than the pronotum, their upper edges not attingent.

d^1. General color dark brown, occasionally with a tinge of green; tegmina short ovate, distinctly shorter than the pronotum. .... *pacificus* Scudd.

d^2. General color grass-green; tegmina long oval, scarcely shorter than the pronotum.

e^1. Slender. Pronotum decidedly angulate behind, very preceptibly widening posteriorly.
coloradensis n. sp.

e^2. More robust. Pronotum with hind margin broadly rounded, of nearly equal width throughout.
curtipennis Scudd.

c^2. Tegmina fully developed or abbreviate, when the latter nearly or fully twice as long as pronotum, their upper edges overlapping.

d^1. Tegmina and wings abbreviate, much shorter than the body. .... *brevipennis* Thom.

d^2. Tegmina and wings distinctly surpassing the abdomen, or sometimes in the female only equalling it.
pratensis Scudd.

A^2. Pronotum decidedly tectiform; both prozona and metazona, both on dorsum and lateral lobes, equally and distinctly rugulose.

b^1. Tegmina elongate, two to five times as long as broad, roundly acuminate at tip. .... *speciosus* Scudd.

b^2. Tegmina ovate, at most one and one-half times as long as wide. .... *floridensis* Morse.

Melanoplus sanguineus new species.

Rather above the medium in size, a moderately robust insect having the general color aspect of *M. atlanis* and its allies, but differing from these species by its more robust hind femora which are rich blood-red inside and below, and in having the hind tibiæ very decidedly bluish-green as in *M. occidentalis* and some other species like *M. glaucipes* Scudder and *M. regalis* Dodge.

Head a little wider than the front edge of pronotum; occiput somewhat elevated above the plane of its disk, eyes fairly large but not very prominent even in the males; vertex a very little wider (♂), or about twice as wide (♀) as diameter of basal antennal joint; the fastigium roundly depressed and rather broadly and deeply sulcate; frontal costa about as wide above as vertex, broadening a trifle below and reaching the clypeus, punctuate above, gently sulcate at ocellus and below; antennæ a trifle longer than head and pronotum together. Pronotum with the sides of anterior lobes about parallel, hind lobe considerably expanding towards the rear, transverse sulci profound, the last about the middle; median carina faint on anterior lobes but prominent on posterior, the latter with its hind edge angulate. Anterior portion of male mesosternum provided with a large blunt protuberance. Tegmina rather narrow, tapering but little apically, reaching beyond the tips of hind femora in both sexes. Anterior and middle femora not greatly enlarged in male, the hind pair moderately robust, a little surpassing the abdomen in both sexes. Extremity of male abdomen neither clavate nor recurved, the subgenital plate short, the apex but little produced and not notched. Supraanal plate broadly triangular, the sides rounded and the apex a little produced, the middle furnished with a rather deep narrow groove which runs from the base nearly to the apex, a little wider and shallower near its termination, the sides undulate near base and projecting over the cerci. The latter nearly equal throughout, a little more than twice as long as greatest width, the apical half bent inwards and with their outer face slightly indented, the lower corner of apex obliquely docked.

Furcula consisting of a pair of moderately depressed, slender, parallel fingers equal and attingent on basal half, tapering for a short distance and slender and equal in outer third, slightly less than half as long as the supraanal plate.

General color varying from a pale testaceous to a dull wood brown, in the lighter individuals tinged above with ferruginous. Sides of head back of the eyes, and pronotum to last transverse incision provided with a well defined piceous band, in some specimens a trifle interrupted by light patches. Occiput usually provided with a similar dark band that begins at the vertex and extends backward to front edge of pronotum. Disk of latter usually pale, but sometimes becoming a little infuscated in middle. Tegmina provided with a discal row of fuscous dots in a pale field, beyond the basal half these also occupy the remainder of the wing. Hind femora provided above and on upper half of outer face with three dusky bands, the apex black preceded by a pale annulus, inner face and lower outer edge, together with lower sulcus, bright blood red; hind tibiæ bluish-green, the knees and genicular lobes of femora bluish-white.

Length of body, ♂, 22.5 mm., ♀, 25 mm.; of antennæ, ♂, 9.5 mm., ♀ 10 mm.; of pronotum, ♂, 5.1 mm., ♀, 5.5 mm.; tegmina, ♂, 20 mm., ♀, 21 mm.; of hind femora ♂, 13 mm., ♀, 14 mm.

Habitat. ♂s and ♀s Lamar and Las Animas, Colorado.

This insect would fall in Scudder's table for the separation of our species of Melanoplus near *bruneri*, *excelsus* and *utahensis*. The table would have to be modified for its reception as follows. (Bottom page 131):

g^2. Apical margin of subgenital plate of male conspicuously elevated above the lateral margins and sometimes greatly prolonged posteriorly; mesosternum of male in front of lobes with a central swelling, forming a blunt tubercle (5. Utahensis series).

- h^1. Apical margin of subgenital plate of male entire; lobes of furcula not exceptionally broad.
  - i^1. Subgenital plate only moderately prolonged. *sanguineus* n. sp.
  - i^2. Subgenital plate greatly but not excessively prolonged.
    - j^1. Interval between mesosternal lobes of male more than twice as long as broad, of female a little longer than broad; male cerci more than twice as long as broad; apical margin of subgenital plate of male, as seen from behind, subtruncate .... *bruneri* Scudd.
    - j^2. Interval between mesosternal lobes of male much less than twice as long as broad; of female transverse; male cerci less than twice as long as broad; apical margin of subgenital plate of male, as seen from behind, rounded. *excelsus* Scudd.
- h^2. Apical margin of subgenital plate of male deeply notched on either side of middle; lobes of furcula exceptionally broad, subequal throughout; subgenital plate excessively prolonged. *utahensis* Scudd.

Melanoplus tristis new species.

A rather small, slender, short-winged insect that bears a strong resemblance to *M. artemisiæ* but which more properly belongs to the Aridus series since it has the cerci and furcula of the male as found in the last named species. Entire insect quite strongly hirsute or pilose.

General color dark reddish brown, varied with darker brown and piceous. Head about as wide (♀) or a little wider (♂) than the front edge of the pronotum, the occiput a little raised above the plane of the latter; eyes large and quite prominent, sub-globular in the male, considerably less prominent and with the anterior edge decidedly straight in

female; vertex a trifle narrower (♂) or somewhat wider (♀) than the basal antennal joint, roundly depressed and quite deeply sulcate with the lateral carinæ rather coarse; frontal costa prominent, plain, the sides nearly parallel, a little wider than the vertex between the eyes in both sexes and reaching the clypeus. Antennæ slender, of moderate length, about reaching, ♀, or somewhat surpassing, ♂, the tip of pronotum. The latter with the sides of anterior lobes somewhat tumescent in ♂, smooth in ♀, no wider at last transverse incision than in front, the dusky band at sides furnished near the center above with a light patch, the posterior lobe a little the shorter, expanding and broadly rounded behind, its entire surface quite profusely punctate; median carina nearly equally prominent throughout. Prosternal spine coarse, conical, moderately long, directed a little to the rear and with the apex blunt. Tegmina lateral, elongate oval, reaching to or a little beyond the apex of the first abdominal segment. Abdomen with the sides strongly piceous, especially in the ♂s. Hind femora rather slender, not quite reaching (♀) or a little surpassing (♂) tip of abdomen, flavous inside and below, crossed on upper half by two dusky bands, the apex also dark; middle and front femora only moderately swollen or obese in males; hind tibiæ dull plumbeous, profusely hirsute. Apical portion of male abdomen only gently club-shaped, the tip very little upturned, the subanal plate entire at apex, in nowise notched or produced; supraanal plate triangular, about equally long and broad, the sides straight, the tip angulate; the furcula as described and figured for *M. aridus* Scudd. (Pl. xiv, fig. 3); cerci also as in that species, except, perhaps, that they may be slightly longer in proportion and a little more bent inwards on their outer half.

Length of body, ♂, 13.5 mm., ♀, 18-20 mm.; of antennæ, ♂, 7 mm., ♀, 6.5 mm.; of pronotum, ♂, 3.1 mm., ♀, 4 mm.; of tegmina, ♂, 2.6 mm., ♀, 3 mm.; of hind femora, ♂, 8 mm., ♀, 9 mm.;.

Habitat. Antonita, Dolores and Durango, Colo., 3 ♂s and 5 ♀s August (Collection Colo. Agr. College).

In order that the position of this species may be more clearly indicated the following portion of Scudder's table is modified so as to include it and is here appended:

g^1. Cerci of male long and very slender, in the middle not one-half the width of the frontal costa, last dorsal segment of male with a pair of strongly oblique submedian sulci outside the furcula; subgenital plate not elevated apically (3. Aridus series).
- h^1. Hind margin of pronotum truncato-emarginate; disk of metazona fully twice as broad as long; tegmina relatively slender, widely distant.
  - i^1. Disk of pronotum coarsely and uniformly punctate; cerci of male apically enlarged and inferiorly accuminate at apex. *humphreysii* Thom.
  - i^2. Disk of prozona coarsely punctate only along anterior margin; cerci of male apically equal, round at tip. *nitidus* Scudd.
- h^2. Hind margin of pronotum obtuse angulate or broadly rounded; disk of metazona less than twice as broad as long; tegmina variable.
  - i^1. Larger (♂ 17.5 mm.); tegmina relatively broad, approximate, at least in the male.................................... *aridus* Scudd.
  - i^2. Smaller (13.5 mm.); tegmina quite slender, lateral, and greatly separated above in both sexes.................*tristis* n. sp.

Melanoplus flabellifer brevipennis new variety.

The specimens before me, eight in number, and coming from Paonia and Palisades in western Colorado agree quite well with the general

description of *M. flabellifer*, only that all of them lack the fully developed tegmina and wings of that insect. The specimens from Palisades are decidedly tinged with rufous, while those collected at Paonia are cineroplumbeous as indicated for the normally long-winged form.

Length of body, ♂, 14-16 mm., ♀, 21 mm.; of antennæ, ♂, 7.5 mm., ♀, 7 mm.; of tegmina, ♂, 5.5 mm., ♀, 7 mm.; of hind femora, ♂, 8.5-9 mm., ♀, 10-11 mm.

Habitat. 4 ♂s and 1 ♀, Palisades, Colorado, July 8, 1901; 2 ♂s and 1 ♀, Paonia, Colorado, September 20, 1903, (Collection Colorado Agricultural College).

The following synoptic table which has been somewhat modified from Scudder's (Revis. Melanopli, pp. 124 and 130, and Suppl. p. 160) will give at a glance the characters separating the various recognized forms belonging to the series:

- *d*1. Cerci of male very broad and short, not more than twice as long as the middle breadth, and broadly rounded at apex. (2. Flabellifer series.)
  - *e*1. Tegmina fully developed.
    - *f*1. Cerci of male twice as broad in broadest as in narrowest portion.
      - *g*1. Subgenital plate of male with a distinct though minute independent apical tubercle.......... *occidentalis* Thom.
      - *g*2. Subgenital plate of male with only one obscure trace of apical tubercle.......... *cuneatus* Scudd.
    - *f*2. Cerci of male with no striking inequality in breadth. *flabellifer* Scudd.
  - *e*2. Tegmina more or less abbreviated.
    - *f*1. Tegmina about half as long as the abdomen and much longer than the pronotum.
      - *g*1. Cerci of male broadly longitudinally sulcate apically, as in flabellifer.......... *flabellifer brevipennis* n. var.
      - *g*2. Cerci of male not longitudinally sulcate apically.
        - *h*1. Interval between mesosternal lobes of male twice as broad posteriorly as anteriorly, the inner margins of the lobes regularly divergent; interval in female longer than broad; cerci of male but little longer than broad.......... *discolor* Scudd.
        - *h*2 Interval between mesosternal lobes of male nearly equal breadth in front and behind, the inner margins of the lobes convex; interval in female transverse; cerci of male nearly twice as long as broad. *simplex* Scudd.
    - *f*2. Tegmina shorter than pronotum.
      - *g*1. Furcula of male only as long as the last dorsal segment; cerci in apical half equal and deeply sulcate longitudinally, so as to appear bent at right angles. *rileyanus* Scudd.
      - *g*2. Furcula one-fifth as long as supraanal plate; cerci in apical half tapering, not sulcate.......... *blandus* Scudd.

Melanoplus dimidipennis new species.

A brachypterous insect the size of which is slightly below the medium and in which the tegmina and wings reach a trifle beyond the middle of the abdomen. Legs, under parts, and abdomen very light colored, the latter almost white except the two basal segments which for the most part are black on sides and above. Pleuræ and upper half of sides of front lobe of pronotum also very strongly marked with fuscous, their ground color along with greater portion of head light plumbeous. Hind tibiæ dirty yellowish-white with a greenish tinge.

Entire insect sparsely clothed with rather long erect light-colored hairs. Head a little wider than front edge of pronotum, the eyes only moderately prominent, a trifle longer than the cheeks below them; vertex rather broad, nearly twice the diameter of basal joint of antennæ, the fastigium shallowly but broadly sulcate, depressed and roundly uniting with upper extremity of the broad prominent frontal costa, the latter with straight edges and expanding but little below where it reaches the clypeus, broadly sulcate at ocellus and below and with a few scattered punctures above. Antennæ a little longer than combined length of head and pronotum. Pronotum with the anterior lobes a very little longer than the hind lobe, smooth and shining, the sides parallel; hind lobe diverging posteriorly, the surface profusely punctate, the hind margins of disk broadly angulate; median carina quite conspicuous on posterior lobe, almost obliterated on anterior lobes; transverse sulcus rather prominent, especially the posterior one which is profound and nearly straight. Prosternal spine rather long, fairly stout, regularly pyramidal, straight and with the apex rounded. Space between mesosternal lobes about half again as long as broad, divergent behind. Anterior and middle femora not especially heavy; the hind pair somewhat robust. Apical portion of ♂ abdomen very little or not at all enlarged; subgenital plate longer than wide, directed backward and gently upward, the extreme apex a little produced, entire but with the surface just before it depressed so as to give it the appearance of being notched as in atlanis and allies; supraanal plate broadly triangular, the sides sinuate and with the edges on basal half raised, the middle provided with two rather prominent nearly parallel carinæ inclosing a profound longitudinal channel which reaches from the base nearly to the apex, but which is interrupted a little beyond the middle by a low cross ridge joining the bounding walls. Marginal apophyses a little longer than width of preceeding segment, evenly tapering to a point, their bases touching, directed backwards and outwards so that their tips cross beyond the outer edge of the walls of central fovea of plate. Cerci about twice as long as broad, of nearly equal width, their lower outer edge gently truncate and the apex rounded, directed backward and inward.

Length of body, ♂, 18 mm.; of pronotum, 3.4 mm.; of antennæ, 7 mm.; of tegmina, 8 mm.; of hind femora, 10.25 mm.

Habitat. Fort Collins, Colorado, a single ♂ on August 16th.

By the use of Scudder's table for separating the species of Melanoplus as published in his "Revision of the Melanopli" this insect seems to come near *M. dawsoni*. In the characters of the tip of male abdomen it reminds one a little of *M. intermedius*, but other characteristics throw it out of the *atlanis* group.

The Bees of the Genus Nomada Found in Colorado,

With a Table to Separate All the Species of the Rocky Mountains.

BY T. D. A. COCKERELL.

When I undertook to work up the species of *Nomada* contained in the collection of the Colorado Agricultural College, I supposed that I should find a few new ones, but that the great majority would be well-known forms long ago discovered by Morrison, Ridings, and others. I find that the collection contains 29 species and varieties, and of these no less that 15 are new. Two others represent undescribed sexes of species previously known. This result serves to indicate the richness of the Agricultural College collection in rare and new forms, and the great value of the material gathered together by Professor Gillette and his associates. I have included in the table of species all those known to occur in Montana, Wyoming, Colorado and New Mexico. Some synonyms and doubtful records have been omitted. Our knowledge of the more northern species, from Wyoming and Montana, is exceedingly incomplete, but it is perhaps not without significance that the few species known from these states all range eastward. The species of Colorado, on the other hand, appear to represent a largely endemic fauna, though some eastern elements appear, particularly in the north. It is possible to separate the species into three groups, those which belong to the Rocky Mountain fauna proper,

those which are modified representatives of eastern species, and have probably reached Colorado in comparatively recent times, and those which are identical with species found east of the plains. Examples are as follows:

(1.) Rocky Mountain Fauna.—*N. rubrella*, *schwarzi*, *martinella*, *scita*, *grandis*, *civilis*, *etc.*

(2.) Modified eastern types.—*N. lepida*, *dacotana*, *vegana*, *zebrata*, *luteopicta.*

(3.) Typical eastern species.—*N. bella*, *albofasciata*, *cuneata superba*, *vincta.*

A few appear to be modifications of northwestern types; such are *taraxacella*, *pecosensis*, and possibly a few others. How far the species extend westward through Utah, etc., cannot be stated, owing to our almost complete ignorance of the *Nomadæ* of that region; but the California *Nomada*-fauna is very distinct from that of Colorado, and the comparatively few species seen from Nevada indicate the extension of the Californian fauna, at least in part, into that state. The same indications exist for Idaho.

The *Nomadæ* of the mountains of northern New Mexico naturally resemble those of Colorado to a considerable extent, but our present lists show a rather surprising amount of difference, perhaps mainly the result of inadequate collecting. The species of southern New Mexico are different, and belong to a southwestern fauna which no doubt extends into Arizona and northern Mexico, though no knowledge of the *Nomadæ* of those regions exists, excepting a single record from Juarez in Chihuahua.

It is hoped that the present paper will facilitate the study of *Nomada* in Colorado. The genus offers a very excellent field for research, and I venture to hope that some advanced student of the Agricultural College will interest himself in it. Undoubtedly more new species await discovery, while the habits of none of the species have been investigated. Very many species are known only in one sex, and there are probably some cases in which the opposite sexes of the same species have been described as distinct.

As is well known, *Nomada* is parasitic in the nests of other bees, principally *Andrena* and *Halictus*. This parasitism should be carefully studied, and it is necessary to breed the bees from the nests in order to fully establish it. It is difficult for me to believe that the same species of *Nomada* can be parasitic in nests of both *Andrena* and *Eucera*, as has been reported of *N. alternata* and *N. agrestis*; or in nests of both *Halictus* and *Colletes* as is recorded of *N. furva.*

TABLE FOR THE DETERMINATION OF THE SPECIES.

Vertex and mesothorax smooth and shining; male entirely black, females with a red abdomen (Montana).......**grindeliæ** Ckll.
Not so, never entirely black.. 1.

1. Normally with only two submarginal cells; abdomen red with yellow bands, first segment red without a band (Montana)..**obliterata** Cress.
   Normally with three submarginal cells..................................2
2. Very large and robust, over 13 mm. long, red with abundant yellow markings ....3.
   Smaller, usually much smaller ....4.
3. Basal nervure considerably basad of transverse medial (Colo.)..**grandis** Cress.
   Basal nervure meeting transverse medial (Colo.)...... **magnifica** Ckll.
4. Mandibles bidentate ....5.
   Mandibles simple...14.
5. Males.. 6.
   Females...12.
6. Tegulæ more or less yellow; scutellum usually with yellow spots; abdomen with yellow bands (Colo.)............**lepida** Cress.
   Tegulæ red; scutellum black or red....................................7.
7. Thorax red marked with black..8.
   Thorax black, with or without red spot on the scutellum..........10.
8. Length about 7 mm.; light markings creamy white; metathorax red with a central black mark. (Colo.)........**rubrella** Ckll.
   Size larger; abdominal markings strongly yellow; metathorax entirely black...9.
9. Third antennal joint long; second submarginal cell broad above. (Colo.) ....**schwarzi** Ckll.
   Third antennal joint shorter; second submarginal cell narrow above (N. M.)..............................**schwarzi contractula** Ckll.
10. Size larger, length 9 to 10 mm., abdomen with yellow bands. (Colo.)...**bella** Cress.
    Size smaller .. ..11.
11. Abdomen with white bands. (Colo.).... ....**albofasciata** Smith.
    Abdomen with yellow spots or bands. (Colo.)..........**cuneata** (Rob.)
12. Larger, 10 mm. long or over. (Colo.) . ...**bella** Cress.
    Smaller, 8 or 9 mm. long...13.
13. Red of abdomen dark. (Colo.)........................**cuneata** (Rob.)
    Red of abdomen light. (Colo.) ....**lepida** Cress.
14. Anterior coxæ strongly spined; abdomen strongly punctured......15.
    Anterior coxæ not or hardly spined; abdomen usually very minutely or not distinctly punctured.................................35.
15. Males..16.
    Females ....26.
16. Apex of abdomen entire; supraclypeal mark surrounded by black. (N. M.)...**lippiæ** Ckll.
    Apex of abdomen notched, though sometines feebly..... ....17.
17. Flagellum with a light median area, on each side of which is black..18.
    Flagellum ordinary, not so colored..................................21.
18. Tegulæ pale yellow or whitish; supraclypeal mark present.......19.
    Tegulæ deep ferruginous; ground-color of abdomen nearly all red. (Colo., Mont.).... ....**americana dacotana** Ckll.
19. First abdominal segment largely red, without light markings. (N. M.) ....**sophiarum** Ckll.
    First abdominal segment black or almost, with a narrowly interrupted cream-colored band.....................................20
20. Abdomen comparatively narrow; legs clear light red. (Colo.)...**scita** Cress.
    Abdomen broad; legs darker. (Colo.).................**martinella** Ckll.
21. Metathorax with yellow marks. (Colo., N. M.)........**vegana** (Ckll.)
    Metathorax without yellow marks.....................................22
22. Mesothorax reddish, size rather large; wings dark. (Colo.) ....**lamarensis** Ckll.
    Mesothorax entirely black, size smaller 23

23. Labrum entirely light red; light markings primrose-yellow; wings clear, strongly clouded at apex. (Colo.)..........**uhleri** Ckll.
Labrum yellowish-white. (Colo.)... ....**snowi** Cress.
Labrum blackish, or with a large black spot........................24
24. Light markings white; flies in spring. (N. M.)..........**vierecki** Ckll.
Light markings yellow; fly in middle and late summer 25
25. Ventral surface of abdomen with two light bands. (N. M.) **crucis** Ckll.
Ventral surface of abdomen dark with only minute light marks (N. M.)............ ....**neomexicana** Ckll.
26. Abdomen red, without light bands.................................27.
Abdomen with light bands...... ....28.
27. Flagellum clear red. (N. M., Colo.)...................**martinella** Ckll.
Flagellum strongly dusky. (Colo., Mont.) ....**americana dacotana** Ckll.
28. Mesothorax reddish (here expect the unknown ♀ of **lamarensis** Ckll.)
Mesothorax black, with little if any red............................29.
29. Abdomen red with white bands ....30.
Not so, ground-color of abdomen mainly or wholly black.........31.
30. Mesothorax densely punctured. (Colo.)..................**ridingsii** Cress.
Mesothorax with well-separated punctures on a shining ground. (N. M.)....................................**vierecki** Ckll. var.
31. Lateral face-markings white or yellowish white. ....32.
Lateral face-markings yellow.......................... 33.
32. Mesothorax densely punctured (Colo.)..................**snowi** Cress.
Mesothorax sparcely punctured on a shining ground (N. M.) ....**vierecki** Ckll.
33. Mesothorax with well separated punctures on a shining ground; ground color of first abdominal segment red (Colo.)....................................**vegana nitescens** Ckll.
Mesothorax densely punctured........................... .....34.
34. Metathorax with yellow spots (Colo., N. M.).............**vegana** Ckll.
Metathorax without yellow spots (N. M.) ....**neomexicana** Ckll.
35. Abdomen with numerous entire (or some slightly interrupted) light bands..36.
Abdomen with light bands, more or less widely interrupted, at least on some of the segments.................................59.
Abdomen red, with small yellow spots (sometimes bands on apical segments) or no light markings........................ 66.
36. Abdominal bands white or yellowish-white; no light markings on head or thorax; venter of abdomen ferruginous, immaculate...37.
Abdominal bands yellow...38.
37. Scutellum strongly bilobate; wings paler (Colo.)........**parata** Cress.
Scutellum not strongly bilobate; wings darker (Colo.). .**munda** Cress.
38. Legs yellow and black, without very much red.. ....39.
Legs wholly or mainly red, or red and yellow .... 40.
39. Smaller; third antennal joint shorter than fourth on the under (light) side (Colo.)...................................**civilis** Cress.
Larger; third antennal joint longer than fourth on the under side (N. M.)......................................**pecosensis** (Ckll.)
40. First abdominal segment without yellow; ♂s.......................41.
First abdominal segment with yellow..............................43.
41. First abdominal segment black;scutellum black(N.M.)**ruidosensis** Ckll.
First abdominal segment red and black ....42.
42. Size larger, scutellum red (Colo.)...................**coloradensis** Ckll.
Size small, scutellum black with small light spots (Colo.) ....**coloradella** Ckll.
43. First abdominal segment black and red, with a yellow spot on each extreme lateral margin; flagellum stout, third antennal joint shorter than fourth; basal nervure basad of transverse-medial. ....44.
First abdominal segment with a yellow band, entire or interrupted ....45.

44. Flies in June; a good deal of yellow on head and thorax (Colo.)........ **crawfordi** Ckll.
Flies in May; no yellow on head and thorax (Colo.)... **collinsiana** Ckll.
45. Metathorax ferruginous and black, without any yellow; ♂s........46.
Metathorax entirely black..47.
Metathorax black with rather small light spots; lateral face-marks broad, but not or hardly going above level of antennæ; apical plate of abdomen more or less notched; ♂s .....51.
Metathorax with two large yellow (or yellow and red) spots.......52.
46. Metathorax black without much ferruginous; scutellum and postscutellum yellow; apical plate of abdomen entire; flies in August (N. M.)........ **xanthophila** Ckll.
Metathorax with more red; scutellum red, postscutellum yellowish; size smaller; apical plate of abdomen deeply notched (Colo.)........ **libata** Cress.
47. Size larger; tegulæ yellow; apical plate of ♂ abdomen entire (Colo., Wyo.)........ **superba** Cress.
Size much smaller ....48.
48. Tegulæ yellow (Colo)........ **luteopicta** Ckll.
Tegulæ ferruginous..49.
49. Head and thorax with much red; larger; flies in sping; ♀ (N. M.)........ **placitensis** Ckll.
Head and thorax without red; smaller; apical plate of abdomen notched; ♂s..50.
50. Antennæ very long, denticulate beneath; fourth joint very long, at least twice as long as third on upper side (N. M., Colo.)........ **fragilis** Cress.
Antennæ not so long, not denticulate beneath; fourth joint not nearly twice length of third on upper side (Colo.) **pallidella** Ckll.
51. Supraclypeal mark present; metathorax with four reddish or yellowish spots, two being on the enclosure (Mont.)... **elrodi** Ckll.
Supraclypeal mark absent; metathorax with two small oval yellow spots (Colo.)........ **gillettei** Ckll.
52. Basal nervure meeting transverse-medial or falling short of it; species (at least **vincta** and **zebrata**) flying in late summer and early fall ....53.
Basal nervure beginning decidedly (often greatly) basad of transverse-medial..54.
53. Apical plate of ♂ abdomen entire; mesothorax of ♂ wholly black, or with very narrow reddish lateral margins, of ♀ black or red and black (Colo.)........ **vincta** Say.
Apical plate of ♂ abdomen slightly notched; mesothorax of ♂ with yellow lateral margins, of ♀ red (Colo., N. M.) **zebrata** Cress.
♂ unknown; mesothorax of ♀ black with yellow lateral margins; thorax narrower than in **zebrata**; yellow of metathorax intruding on enclosure (which is not the case in **vincta** or **zebrata**); third antennal joint considerably shorter than fourth (it is considerably longer than fourth in **zebrata** and **vincta**) (Colo.)........ **perivincta** Ckll.
54. Mesothorax black, with the anterior lateral corners red; apical plate of abdomen truncate, not appreciably emarginate; sides of metathoracic enclosure yellowish; ♂ (Colo.) .... **agynia** Ckll.
Mesothorax red, with or without a black band; ♀s ....55.
55. Flagellum strongly blackened at end, mesothorax with a broad median black band; scutellum yellow without a median dark stripe or shade; basal nervure a short distance basad of transverse-medial; third antennal joint a little shorter than fourth (Colo.) ...... **perivincta** var. **semirufula** Ckll.
Flagellum red, not blackened at end ....56.
56. Ventral surface of abdomen yellow, with narrow red bands; scutellum at least mostly yellow..57.

Ventral surface of abdomen red banded with yellow; third antennal joint shorter than fourth ....58.
57. Third antennal joint long; fourth considerably longer than fifth (Colo.) .... **morrisoni** var. **flagellaris** Ckll.
Third antennal joint shorter; fourth scarcely longer than fifth (Colo.) .... **morrisoni** Cress.
58. Scutellum prominent, entirely red; tegulæ strongly punctured; third antennal joint much shorter than fourth (Colo.) .... **rhodoxantha** Ckll.
Scutellum not prominent, with a yellow band at base; tegulæ smooth and shining; third antennal joint a little shorter than fourth (Colo.) .... **dilucida** Cress.
59. Markings white or cream-color ....60.
Markings yellow ....62.
60. Ferruginous species; third antennal joint much longer than fourth (N. M.) .... **gutierreziæ** Ckll.
Black or red and black species ....61.
61. Scutellum black with two cream-colored spots; head and thorax without red; third antennal joint slightly longer than fourth; ♂ (N. M.) .... **aquilarum** Ckll.
Scutellum ferruginous; thorax with much red in both sexes, third antennal joint much shorter than fourth (Colo.) **accepta** Cress.
62. ♂s; head and thorax black ....63.
♀s; head and thorax red, usually marked with black ....64.
63. Smaller, length not over 8 mm.; scutellum black; upper half of clypeus black (N. M.) .... **beulahensis** Ckll.
Larger, length 10 mm.; scutellum red; clypeus yellow (Colo) .... **vicinalis** Cress.
64. Tubercles and postscutellum yellow; venter of abdomen largely yellow (Colo.) .... **alpha** Ckll.
Tubercles and postscutellum red; venter of abdomen red without yellow ....65.
65. Front marked with black; a black stripe on mesothorax; apex of flagellum fuscous; second abdominal segment with yellow lateral spots, third and fourth with bands (Colo.) .... **libata** Cress.
Front wholly red; no black stripe on mesothorax; flagellum wholly red; second and third abdominal segments with large wedge-shaped yellow marks, fourth with a band interrupted on each side (Colo.) .... **coloradensis** Ckll.
66. Head and thorax black, abdomen black and rufous ....67.
Head red marked with black; thorax black, a large mark on each side of mesothorax, the scutellums and most of pleura, red; clypeus yellow; abdomen without yellow; ♂ (Colo.) .... **adducta** Cress.
Head and thorax red; clypeus red ....68.
67. Clypeus reddish; legs rufous; basal nervure a short distance basad of transverse-medial; third antennal joint a little longer than fourth (N. M.) .... **pennigera** Ckll.
Clypeus black; legs black (N. M.) .... **sidæfloris** (Ckll.)
68. Larger, about 7 or 8 mm. long; second abdominal segment with yellow spots ....69.
Smaller, about 6 mm. long ....71.
69. Lower anterior orbits very narrowly yellow; third antennal joint very much shorter than fourth (N. M.) .... **taraxacella** (Ckll.)
Lower anterior orbits not yellow ....70.
70. Fourth and fifth abdominal segments with yellow bands, not nearly reaching lateral margins; third antennal joint nearly as long as fourth (Colo.) .... **luteopicta** Ckll.
Fourth and fifth abdominal segments without yellow bands; third antennal joint much shorter than fourth (Colo.) .... **sayi** Rob.
71. Abdomen red without yellow spots; scape stouter and lighter; metathorax without a black band (Colo.) .... **rhodosomella** (Ckll.)

Abdomen with spots; scape darker and more slender; metathorax with a black band (Colo.) .... **coloradella** Ckll.

In addition to the species recorded in the table, *Nomada (Micronomada) putnami*, Cress., *N. (Holonomada) affabilis*, Cress., *N. (Xanthidium) citrina*, Cress., and *N. (Nomada* s. str.*) pygmæa*, Cress., have been recorded from Colorado, but the records appear to require confirmation. The first three are indicated in comparison with Rocky Mountain species in tables in Proc. Acad. Nat. Sci. Phila., 1903, pp. 581, 582 and 609. For *N. affabilis* also see Robertson, Canadian Entomologist, 1903, p. 177. *N. pygmæa* (♂) is about six mm. long, mandibles simple; clypeus, a spot above it, labrum, mandibles and face narrowly on each side of clypeus, yellow; orbits ferruginous; abdomen granular.

DESCRIPTIONS AND NOTES.

Nomada (Gnathias) lepida, Cresson.

Evidently very common at Fort Collins, Colorado, numerous specimens of both sexes sent by Prof. Gillette. The dates are from May 8 to 17.

The insect which I described (Proc. Acad. Nat. Sci. Phila., 1903 p. 600) as the probable ♀ of *N. schwarzi*, is really the ♀ of *lepida*.

Nomada (Gnathias) cuneata, (Robertson).

A ♂ (sent by Prof. Gillette) was collected at Fort Collins, foothills, May 10, 1900, by E. S. G. Titus. Others seem intermediate between *lepida* and *cuneata*, and I rather expect that it will become necessary to regard the latter as a subspecies of *lepida*. At the same time, numerous eastern specimens of *cuneata* show no intergradation with *lepida*. It is perhaps a case like that of the bird-genus *Colaptes*.

Nomada (Gnathias) albofasciata, Smith.

Two ♂s (sent by Prof. Gillette); one Fort Collins, foothills, April 24, 1900, by Titus; the others "Colo. 1581" taken at Fort Collins, foothills, May 6, 1904, by C. F. Baker.

Nomada (Gnathias) bella, Cresson.

A Colorado ♀ without locality label (sent by Prof. Gillette).

Nomada (Gnathias) rubrella, new species.

♂; length hardly 7 mm.; closely allied to *N. schwarzi*, but differing as follows: Smaller; light markings creamy-white instead of yellow; sides of front narrowly, sides of vertex broadly (and enclosing a yellow spot), a band behind ocelli, and posterior orbital margins ferruginous; mesothorax dark ferruginous with a median black stripe; most of pleura ferruginous; metathorax (all black in *schwarzi*) ferruginous with an elongate black mark; middle femora with a little more than the basal third black behind, the black very sharply defined from the red; tegulæ smaller and yellower; first abdominal segment (black right across at base in *schwarzi*) with very little black, only forming lateral hook-shaped marks; apical portion of abdomen not blackish; apical plate much less strongly notched. In both there is a yellowish mark at the apex of the abdomen beneath.

Habitat. Fort Collins, Colorado, May 18, 1901, near foothills, taken by Mrs. Laura Titus from plum blossoms.

Nomada (Nomadula) americana variety **dacotana,** Cockerell.

♂, ♀ (sent by Prof. Gillette); the ♀s are not distinguishable from true *americana*. Fort Collins, Colorado, May 28 and June

17. Also Colorado 2562 (Fort Collins, June 11, 1893, C. P. Gillette, collector), 1170 (Fort Collins, June 13, 1893, C. P. Gillette, collector) and 623 (Fort Collins, July 5, 1903, C. P. Gillette, collector).

Nomada (Nomadula) martinella, Cockerell.

Three ♀s (sent by Prof. Gillette) are variable, and do not support the idea that the Colorado form is distinct from that of New Mexico. Two are from Fort Collins, May 28 and June 19; the other is marked Colorado 2521 (Fort Collins, May 28, 1897, E. S. G. Titus, collector).

The ♂ of *N. martinella* has not been described, but I find three specimens in the Colorado collection. They are closely allied to *N. scita*, but are readily separated by the broader abdomen and darker legs; the tegulæ are bright lemon yellow with a hyaline spot; the thorax is covered with coarse hair which has a decided brownish tint. The scape is more swollen than in *scita*, and the yellow of the face is darker and stronger. The hind femora are stout with the lower edge decidedly concave. The scutellum is black. These ♂s are marked Fort Collins, May 20 and 21, and Colorado 2521.

Nomada (Micronomada) vegana, (Cockerell).

This was described as a variety of *N. modesta*, but it seems to be a distinct though closely allied species. The ♂s are like true *modesta*, but uniformly small. Prof. Gillette sends five ♂s and two ♀s. They are mostly from Fort Collins, July 4 to 20; one is marked Colorado 1204 (Fort Collins, June 26, 1893, attracted to Helianthus leaves by their secretions.—C. F. Baker, collector).

Nomada (Micronomada) vegana variety **nitescens,** new variety.

♀, just like *vegana*, except that the mesothorax, instead of being very closely punctured, has large irregularly scattered punctures on a shining ground. The ground-color of the first abdominal segment is red, and there is a red supraclypeal mark. Perhaps a distinct species.

Fort Collins, Colorado, August 8, 1899 (E. S. G. Titus, collector).

Nomada (Micronomada) lamarensis, new species.

♂, length about 9½ mm.; red, yellow and black. Markings bright lemon yellow, the pattern as in *N. vegana*, except that the mark on the pleura is narrower, the marks on the metathorax are wholly absent, and the band on the second abdominal segment is extremely broad; the ground-color of the body is dark red, becoming black on the vertex, the anterior part of mesothorax, and the enclosure of metathorax, and almost black on the pleura below the yellow band; the fourth abdominal segment is black anteriorly to the rather narrow yellow band, and the fourth ventral segment is black with two transverse reddish stripes, one on each side. The insect is much more robust than *vegana* (in build similar to *wheeleri*), and the head and thorax are very coarsely punctured; the punctures of the mesothorax are extremely large, and many of them confluent. Those of the pleura also very large. Sides of vertex with the

punctures very irregular, but leaving a good deal of shining surface; antennæ red, third joint longer than fourth, flagellum blackish above; tegulæ yellow with a ferruginous spot and rim; wings dusky, the apex very dark; stigma orange-ferruginous; nervures fuscous; second submarginal cell large and nearly square, receiving the recurrent nervure just beyond the middle; basal nervure meeting transverse-medial; ventral surface of abdomen without yellow markings; legs red, hind coxæ with a yellow spot, hind tibiæ with some yellow; anterior coxæ with red spines. Apical plate deeply notched.

One from Lamar, Colorado, June 17, 1900, (E. D. Ball, collector). This cannot be the ♀ of *N. wheeleri*, as that species has the submarginal cells quite different; in *wheeleri* the third submarginal cell is at least as broad above as the second, in *lamarensis* the second is rather more than twice as broad above as the third. The wings are much darker in *lamarensis* that in *wheeleri*. *N. lamarensis* resembles *N. crassula* in the very coarsely punctured mesothorax, and also in build, but differs in its red color, more strongly (indeed very strongly) bilobed scutellum, presence of a supraclypeal mark, etc.

Nomada (Micronomada) uhleri, new species.

♂; length about 7½ mm.; similar to *N. vegana* but more robust, the abdomen of spherical form, after the manner of *N. erigeronis*; markings light primrose-yellow (deep yellow in *vegana*), similar to those of *vegana*, but the labrum is entirely light red, the scape has only a yellow shade, and the metathorax is wholly without yellow marks; the mesothorax is densely punctured, more densely and coarsely than in *vegana*; ground-color of head and thorax black, but middle of mandibles red, a small red spot beneath the wings, and a red patch above middle and hind coxæ; antennæ red, scape and basal part of flagellum blackened above, the black not ending abruptly; tegulæ primrose-yellow, with hyaline spot and margins; wings clear, with very dark apex; stigma ferruginous, nervures piceous, second marginal cell nearly square, and receiving the recurrent nervure very near the middle; in one wing of the type the first recurrent nervure is divided at the end, forming an areolet under the second submarginal cell; basal nervure meeting transverse-medial, and third antennal joint longer than fourth, as usual in *Micronomada*; spines on anterior coxæ red and very long; legs red, anterior tibiæ with a light yellow stripe in front, hind coxæ with a yellow mark; there is a yellowish spot at the apex of each femur. and at the end of the hind tibia; abdomen dark brown above, clear red on first segment, beneath dark ferruginous, with linear yellowish markings; above, the first segment shows a broad primrose-yellow band, the second an extremely broad band, narrower in the middle, and the others bands which are hidden by the retraction of the segments; apical plate strongly notched.

One from Fort Collins, Colorado, August 18, 1900, (E. S. G. Titus, collector). Named after Dr. Uhler, who was one of the first to collect species of *Nomada* in Colorado.

Nomada (Holonomada) grandis, Cresson.

One marked Colorado 2509, taken in the foothills near Fort Collins, May 26, by C. P. Gillette. This differs from *N. magnifica* in the venation, but otherwise they are practically the same. I do not know whether the differential character, which in the case of *Gnathias* is certainly subgeneric, can here be only varietal.

Nomada (Holonomada) pecosensis, (Cockerell).

A ♂ from Palisades, Colorado, May 7, 1901, from apple bloom, (C. P. Gillette collector). It differs from the ♀ in having the pleura with a comparatively small yellow mark, and no yellow spot in front of anterior ocellus; the abdomen also is more inclined to be punctured. The species is the Rocky Mountain representative of *N. edwardsii*, from which it is easily known by the red color on the legs. Except as to the abdomen, the ♂ *N. pecosensis* agrees with the description of *N. intercepta*, Smith, from Vancouver I., which is evidently a *Holonomada*.

Nomada (Holonomada) vincta, Say.

Perfectly genuine *vincta*, one of each sex, were taken by F. C. Bishopp, at Fort Collins, Colorado, September 4 and 12, 1903, from sunflowers. (Helianthus sp.)

Nomada (Holonomada) zebrata, Cresson.

A ♀ collected by E. S. G. Titus at Fort Collins, July 28, 1900. When we consider *N. zebrata*, *vincta*, *morrisoni*, etc., the distinctions between *Holonomada* and *Xanthidium* appear to completely break down. *Holonomada* might possibly be restricted to *superba*, *edwardsii*, *pecosensis*,and their immediate allies; if this is not done, *Xanthidium* must I think be given up.

Nomada civilis, Cresson.

Three ♂s; Fort Collins, May 12, 1901, from plum blossoms, (E. S. G. Titus, collector) and one Denver, May 2, 1902.

Nomada (Xanthidium) rhodoxantha, new species.

♀; length about 10 mm., head and thorax ferruginous, strongly and closely punctured; scutellum prominent, bilobed; antennæ long, entirely red, third joint much shorter than fourth, flagellum stout; labrum with a minute denticle; extreme lower corners of face yellow, but no yellow on clypeus or mandibles; upper border of prothorax with a yellow stripe; tubercles and tegulæ ferruginous, the latter strongly punctured; pleura with an obscure yellow spot posteriorly;metathorax with a median black band, on each side of which is a large area (including the sides of the enclosure) variegated with red and yellow; legs red, middle femora at base beneath, and hind femora largely blackish; wings clear with a brownish stain along the nervures, tips dusky; stigma bright ferruginous, nervures brown; second submarginal cell broad above, third greatly narrowed above, its outer margin strongly angled; basal nervure a short distance basad of transverse medial; abdomen minutely rugulose, ferruginous, with broad entire yellow bands on all the segments, basal half of first segment black; venter ferruginous, marked with yellow. The mesothorax has a strongly marked median black band.

One specimen, Colorado, without other locality label.

This has the general appearance of *N. morrisoni*, *luteoloides*, etc. From *luteoloides* it is easily known by the ferruginous, densely punctured (minutely cancellate) scutellum. From *morrisoni* it differs by the much narrower mesothorax, with larger and much more distinct punctures; the shape of the third submarginal cell, etc. From *placitensis* it differs by the much longer fourth antennal joint, the absence of the conspicuous brown hair on vertex and dorsum of thorax, etc. A form of

N. rhodoxantha differing in some slight details of color, has been taken by Dr. Graenicher at Milwaukee, Wisconsin, on June 3.

Nomada (Xanthidium) crawfordi, new species.

♀; length about 11 mm., another red species with entire and broad bright yellow bands on the abdomen, similar to the last, but the first segment has a round yellow spot on each side, instead of a band. The sides of the face broadly, the anterior edge of the clypeus, the labrum, the upper margin of prothorax, the tubercles, two spots on the tegulæ, and four spots on the metathorax, are yellow. The ventral surface of the abdomen is mainly yellow beyond the first segment. The scape is suffused with yellow in front, the flagellum is strongly blackish above towards the end, but the extreme tip is red; the third antennal joint is a little shorter than the fourth; the second submarginal cell is broad above, the third much narrowed above, its outer margin strongly angled; the basal nervure is a short distance basad of the transverso-medial.

It is distinguished from the various similar species thus:

From *N. dilucida* by the mesothorax being entirely red except the narrow anterior border and the median band, which are black; by the scutellum being entirely red; by the metathorax having four yellow spots; by the strongly punctured tegulæ; by the hind femora having a long-oval red mark clean-cut out of the blackish at the base behind; by the hind tibiæ being entirely red, but the basal joint of the hind tarsi yellow behind; and by the first abdominal segment being red, with a yellow spot on each side between two black spots. From *N. rhodoxantha* by the broader form, longer third antennal joint, duskier wings, and quite different pattern of first abdominal segment. From *N. morrisoni* by the longer fourth antennal joint, peculiar color of flagellum, red scutellum, shape of third submarginal cell, etc. From *N. placitensis* by its larger size, yellow on face, much less black on thorax, etc. From *N. zebrata* by the proportions of the antennal joints, red scutellum, etc. From *N. citrina* v. *rufula* by the red pleura and scutellum, the color of the flagellum, the absence of a yellow spot at the apex of the posterior femora, etc. The yellow of the legs is practically confined to the hind tarsi and front knees.

One specimen; Virginia Dale, Colorado, June 20, 1901, F. C. Bishopp, collector. *N. crawfordi* is named after Mr. J. C. Crawford, Jr., in recognition of his work on bees.

Nomada (Xanthidium) collinsiana, new species.

Two ♀s taken by S. A. Johnson, Fort Collins, Colorado, May 11 and 20, 1903. One from wild plum. I had at first considered this a variety of *N. crawfordi*, but it may be kept separate for the present, at any rate. It differs from *crawfordi* thus: A trifle smaller; no yellow whatever on head or thorax; middle of front black, with a red spot in front of anterior ocellus; flagellum red; apical part not blackened; thorax more hairy; tegulæ entirely red; third submarginal cell nearly or not far from as broad above as second; basal nervure more basad of transverso-medial; legs without yellow, except a small obscure spot at base of anterior and middle tibiæ; hind femora red, with a broad black stripe behind, not reaching either end, and on it a band of short yellowish hair; hind coxæ with much black (only a little in *crawfordi*); base and apical margin of first abdominal segment black; pygidial plate narrower, venter ferruginous marked with yellow and black.

Nomada (Xanthidium) perivincta, new species.

A ♀ marked Colorado, without definite locality.

Length $10\frac{1}{2}$ mm.; ground-color of head and thorax black; labrum yellow, with a small reddish spine; mandibles pale ferruginous, with black tips; face below antennæ yellow; the upper part of clypeus, and upper part of supraclypeal area, ferruginous; front with ferruginous bands continued from the lateral face marks, strongly curving inwards; a red spot before middle ocellus; posterior orbital margins rather broadly red; scape ferruginous behind, bright yellow in front; flagellum ferruginous, the last six joints strongly blackened, the extreme apex red; fourth antennal joint much longer than third; mesothorax very coarsely and densely rugoso-punctate, its lateral margins yellow edged with ferruginous; upper border of prothorax, tubercles, scutellum, a spot at each anterior corner, postscutellum, and large quadrate marks on metathorax encroaching on enclosure, all bright yellow; pleura yellow, with a small black and red mark above, and a large black mark surrounded by red below; legs a lively red; hind coxæ with a large black mark behind and a yellow one above; anterior femora yellow in front and apically, middle fomora with less yellow in front, but a large mark at apex, hind femora with a yellow stripe in front and a large black area behind; tibiæ yellow on outer side, hind tibiæ with a black stripe behind; basal joint of hind tarsi mainly yellow; tegulæ shining and sparsely punctured, ferruginous with a yellow spot in front; wings rather yellowish, apex clouded; stigma bright ferruginous, nervures brown; second submarginal cell very broad above, not far from square, receiving the recurrent nervure well beyond its middle; third a little broader below than second, but very greatly narrowed above, its outer margin strongly angled; basal nervure meeting transverso-medial; abdomen minutely rugulose, bright yellow, with the base of first segment, and three broad bands at the junction of the segments, black; hind margin of fourth segment reddish brown, fifth all yellow; venter yellow (reddish on sides of first segment) with three black bands on which are reddish stripes.

N. perivincta differs from *N. vincta* by the considerably larger punctures of the mesothorax, the color of the hind legs, the yellow of metathorax intruding on enclosure, the proportions of the antennal joints, etc. From *N. citrina* it differs by the narrower face, the broad third submarginal cell, etc. From *N. citrina* v. *rufula* by the narrower face, the blackened apical part of flagellum, etc. From *N. rhodoxantha* by the yellow scutellum, color of legs, etc. From *N. sulphurata* by the much narrower first segment of abdomen, broad third submarginal cell, etc. From *N. rivalis* by the markings of thorax and legs, etc.

Nomada perivincta variety **semirufula,** new variety.

A ♀ marked Colorado, without definite locality.

Mesothorax mainly dark red, with a broad median black band, and a good deal of black on the anterior and posterior margins; anterior lateral corners only yellow. Lower part of pleura with a large red patch without black; yellow marks on metathorax margined with red; first abdominal segment considerably broader, its basal half red with a blackish transverse band; venter with black bands only on the first and extreme base of fourth segments. This resembles *N. sulphurata* in the darkened apical part of flagellum, etc., but the first abdominal segment though broader than in the type, is by no means so broad as in *sulphurata*, while the colors of the mesothorax and ventral surface of abdomen, and the shape of the third submarginal cell, are quite different. The basal nervure in

semirufula begins well basad of the transverso-medial, as in *sulphurata* and not as in *perivincta*.

Nomada gillettei, new species.

Named after Professor Gillette, who has done so much for Colorado entomology. The type is a ♂ marked Colorado 2198. Taken at Golden, July 3rd, by C. P. Gillette.

Length 9½ mm.; head and thorax black, densely and coarsely punctured; facial quadrangle considerably broader than long; front concave; labrum, basal half of mandibles, clypeus, very broad lateral face marks ending at level of antennæ, and broad marks beneath eyes, all chrome yellow; antennæ lively ferruginous, fourth joint much longer than third; scape quite swollen, yellow in front, and with a black dash and dot behind; hair of head and thorax scanty, white; upper border of prothorax, tubercles, V-shaped mark beneath, and a spot on each side of the lower part of metathorax, all yellow; scutellum with two minute red spots; legs a lively red, extreme base of anterior and middle tibiæ with an obscure yellowish spot; middle femora with a small black spot at extreme base; hind femora nearly all black behind; tegulæ punctured, whitish tinged with red; wings clear, yellowish along the nervures; stigma and nervures ferruginous; second submarginal cell broad above, receiving the recurrent nervure a little beyond its middle; third at least as broad as second below, but narrowed more than half above, its outer margin bent; basal nervure a short distance basad of transverso-medial; abdomen yellow, the bases of the segments black, their apical margins pale ferruginous; the yellow band on the first segment is interrupted in the middle by a reddish triangle pointing posteriorly; apical plate narrow, feebly notched; venter yellow, banded with dark reddish brown. The face is bare, without the beautiful appressed white hair seen in *N. elrodi*. The colors of the abdomen recall *N. civilis*.

Nomada agynia, new species.

One ♂ sent by Prof. Gillette, marked Colorado 2196, Golden, July, C. P. Gillette, collector.

Length about 9 mm.: black with yellow markings; head broad, facial quadrangle about square; basal two-thirds of mandibles, labrum, clypeus, lateral face-marks (broad below, gradually narrowing to a point at top of eyes) and posterior orbits nearly to summit, all yellow; clypeus with the usual sutural black spots; supraclypeal mark obscure reddish, narrowly surrounded by black; antennæ not very long, third joint much shorter than fourth; scape stout, heavily marked with black on a red field above, yellow below (in front); flagellum dark ferruginous, blackish above, especially towards base; mesothorax dull, very densely and quite coarsely rugoso-punctate, the anterior lateral corners, and a few marks on lateral margin, red; upper border of prothorax, tubercles, scutellum and postscutellum, yellow; pleura red with a broad curved transverse yellow band, and a large black spot beneath; metathorax black in the middle, the sides (encroaching on the enclosure) variegated with red and yellow; tegulæ yellow, large, shining and rather sparsely punctured; wings quite long, hyaline, the apex blackened; stigma ferruginous, nervures fuscous; second submarginal cell broad below, but narrowed above; third broad below, and narrowed more than half above; basal nervure a short distance basad of transverso-medial; legs lively ferruginous, the hind femora and tibiæ darker, the hind femora black behind except at base and apex; middle femora somewhat swollen, with a blackish spot on apical half behind; knees, and a stripe on anterior tibiæ, yellow; abdomen rather broad, closely and minutely punctured; all the segments yellow with black bases and ferruginous apical margins, the yellow of the

first segment with a pair of small reddish sublateral marks; apical plate narrow, truncate, with the faintest suggestion of an emargination; venter yellow with blackish and reddish bands.

This is possibly the ♂ of some described species, but after repeated comparisons, I cannot satisfactorily assign it to any. In my table in Proc. Acad. Nat. Sci. Phila., 1903, p. 559, it runs to *pascoensis*, which it superfiicially resembles, but it is easily known from that by the quite ordinary last antennal joint, the light marks on metathorax, etc.

Nomada pallidella, new species.

One ♂ marked Colorado 566 (Montrose, June 24, 1902, C. P Gillette, collector).

Length about 7½ mm.; black, marked with pale yellow; quite hairy. Facial quadrangle about square: labrum, mandibles except tips, narrow stripe beneath eyes, clypeus and lateral face-marks, yellow, lateral face-marks reduced to a triangle at lower corners of face, which sends a line upwards along orbital margin nearly to level of antennæ; antennæ long, scape ordinary, yellow in front; third joint much shorter than fourth; flagellum dark ferruginous, blackened above; mesothorax dull and very densely rugoso-punctate; tubercles, a small mark on anterior part of pleura, and two spots on scutellum, yellow or yellowish tinged with reddish; metathorax entirely black; hair of dorsum of thorax brownish; tegulæ ferruginous, punctured; wings iridescent, dusky at tips: stigma ferruginous, nervures fuscous; second submarginal cell broad above, third greatly narrowed above; basal nervure meeting transverso-medial, but a little on the basad side; legs red without any yellow; basal half of anterior femora behind, most of basal two-thirds of middle femora behind and beneath, and all of the hind femora except apex, black; hind tibiæ with a blackish dash on inner side: abdomen minutely roughened; light yellow bands on segments two to six not interrupted, but those on four and five enclosing laterally a dark spot: band on first segment with a rather broad median ferruginous interruption, the area posterior to the band also being ferruginous, with two blackish dots; otherwise, the dark parts of the abdomen are black or almost so; apex with long hairs; apical plate quite broad, deeply notched; venter red-brown, with yellow bands bent in the middle and not reaching the lateral margins.

From Robertson's *N. salicis* and *N. simplex* (♂s) this is readily separated as follows:

Apex of abdomen strongly notched .... 1.
Apex of abdomen slightly notched; scutellum black ...... *simplex*.
1. Legs marked with yellow .... *salicis*.
Legs not marked with yellow .... *pallidella*.

The Californian *N. subangusta*, Ckll., is very near to *N. pallidella*, but it has the first abdominal segment narrower; the abdomen, where not yellow, mainly red; the scutellum entirely black, the second submarginal cell narrower; and the red of the flagellum much brighter. In the face-marks, hairy thorax, etc., they agree.

From *N. modocorum*, Ckll., *N. pallidella* is easily known by the much narrower, parallel-sided abdomen, with much paler markings, those of *modocorum* being bright yellow.

Nomada sayi, Robertson.

One ♀ collected by E. S. G. Titus at Virginia Dale, Colorado, July 24, 1899, from wild geranium. The date seems too late for *sayi*, and the specimen is hardly typical; it is not *N. lehighensis*, which flies in July. Probably when we have a good series of the Colorado insect, including both sexes, it will be possible to separate it subspecifically, at least.

Nomada coloradella, new species.

A pair; ♂, Fort Collins, Colorado, June 18, 1900; ♀, Colorado 633 (Dolores, June 18, '92, C. P. Gillette, collector).

♂; length 5½ mm.; head and thorax black, with abundant white hair; labrum, mandibles except tips, clypeus and lateral face-marks, bright yellow; lateral face-marks consisting of triangles occupying the lower corners of face, sending a line upwards to level of antennæ; facial quadrangle somewhat broader than long; antennæ very long; scape moderately stout, yellow in front and black behind; third joint much shorter than fourth; flagellum submoniliform, pointed at apex, bright light yellowish-ferruginous, the first four joints black above; tubercles and tegulæ reddish-testaceous, scutellum with two reddish spots, thorax otherwise all black; wings clear, dusky at apex; nervures and stigma yellowish-ferruginous, marginal cell long; second submarginal broad above, receiving the recurrent nervure far beyond its middle; third submarginal very broad below, greatly narrowed above, its outer margin strongly bent; basal nervure meeting transverso-medial (in *N. sayi* it is a long distance basad of it); legs red, the femora blackened behind and beneath; abdomen ferruginous, basal half of first segment black; a bright yellow band, interrupted in the middle, on segments 2 and 3; yellow hardly apparent on 4, but prominent on 5 and 6; apex with long hairs; apical plate moderately notched; venter ferruginous.

♀; length about 6 mm., red, mesothorax and metathorax each with a single black band; ocelli on a black patch, but front all red; antennæ red, scape with a blackish apical spot on inner side; third antennal joint about as long as fourth; first segment of abdomen practically without black; basal nervure meeting transverso-medial, but on the basad side. The ♂ is to be regarded as the type; it is not quite certain that the ♀ belongs to it, but it is probable enough to justify the association for the present. The ♂, in its color and markings, is like *N. sayi*, but it is easily distinguished by the venation. It differs from *N. rhodosoma* by its smaller size and much lighter antennæ and stigma; from *N. oregonica* by its light orange stigma, and apical half of flagellum not black above; from *N. lehighensis* by its smaller size, and quite different color of antennæ and stigma; from *N. pygmæa* by the absence of supraclypeal mark, and orbits not ferruginous. It is also allied to *N. illinoiensis*. The ♀ resembles *N. rhodosomella*, but is separatel by the characters given in the table.

Nomada luteopicta, new species.

Two ♂s and a ♀ collected by Prof. Gillette; all Palisades, Colorado, May 7, 1901, from apple blossoms.

♂; length about 6½ mm.; head and thorax black, with abundant white hair; labrum, mandibles except tips, narrow stripe beneath eyes, clypeus and lateral face-marks (consisting of a triangle at lower corners of face, sending a line upwards to level of antennæ) all bright-yellow; eyes green; antennæ long, scape rather swollen, yellow in front and black behind; third joint shorter than fourth; fourth shorter than last; flagellum bright clear yellowish-ferruginous, the first four joints black above; tubercles, tegulæ, upper border of prothorax, mark on anterior part of pleura, and two clearly-defined oval spots on scutellum, yellow; wings slightly dusky, apex darker; stigma dark ferruginous, nervures fuscous; second submarginal cell very narrow, or broadened below by the lengthening of the lower basad corner, in which case the recurrent nervure is received much beyond its middle; third submarginal extremely broad below, narrowed more than half above, its outer side strongly bent; basal nervure meeting transverso-medial; legs red, middle and hind coxæ mainly black; middle femora with a black stripe beneath, hind femora mostly black behind; all the knees broadly, and apex of hind tibiæ, yellow; abdomen yellow, the segments ferruginous on apical margin, and more or less black basally; apex with long hairs, apical plate very feebly notched;

venter yellow, ferruginous at base, and with the hind margins of the segments broadly pale ferruginous.

♀; red; mesothorax and metathorax with a median black band; third antennal joint not greatly shorter than fourth; abdomen red, not black at base; second and third segments with a subquadrate bright yellow spot on each side, third also with a pair of yellow dots mesad of the spots, fourth with a yellow band, not reaching lateral margins, fifth with a short broad band; venter without yellow.

The ♂ is to be considered the type. It is closely allied to *N. coloradella*, but larger, with a broader abdomen, with much more yellow. The ♀ is very near to *N. lewisi*, Ckll., but has no yellow at lower corners of face; and has the third submarginal cell much broader. The scutellum of the ♀ is low and scarcely bilobed, as in *N. simplex*, Rob., which is closely allied; but *simplex* has much more black on the head and thorax, and the fourth abdominal segment spotted instead of banded.

Nomada coloradensis, Cockerell.

A pair; the ♂ marked Fort Collins, Colorado, foothills, May 19, 1900, E. S. G. Titus, collector: the ♀ marked Colorado 566, just like the original type. Taken June 24, 1892, at Montrose, by C. P. Gillette. At Milwaukee, Wisconsin, Dr. Graenicher has taken a form of *N. coloradensis*, which may prove to be subspecifically separable.

The ♂ has not been described. It is very similar to several ♂s, from which it is readily separated as follows:

Scape conspicuously swollen, apical plate broad ....1.
Scape ordinary; venter red not spotted with yellow; apical plate narrow ....3.
1. Pleura with much red; metathorax with four red spots; venter with large yellow markings............*bethunei* Ckll.
Pleura and metathorax without red (or pleura with a small red mark)..2.
2. Venter spotted or banded with yellow........*vicinalis* Cresson.
Venter red without yellow. ....*vicinalis* var. *infrarubens* Ckll.
3. Larger; mesothorax marked with red; first abdominal segment with a yellow band ....*armatella* Ckll.
Smaller; metathorax all black; first abdominal segment without a yellow band ....*coloradensis* Ckll.

I am greatly indebted to Mr Rehn for the information that Cresson's type of *N. vicinalis* has the apical plate of abdomen broad, scape normal, base of metathorax more granulose than rugulose, labrum with a very slight median denticle.

N. vicinalis infrarubens is a new variety obtained by Prof. Cordley at Corvallis, Oregon, June 6, 1899. It has the following noteworthy characters; labrum very hairy; ends of linear upward prolongation of lateral face-marks slightly bending from orbits; flagellum bright red, the last joint pointed, the first five joints black above; hair of upper part of thorax (especially scutellum) strongly brownish; tubercles reddish with a yellow spot; tegulæ, scutellum, two stripes on mesothorax, and a small mark on lower part of pleura in front, red; first abdominal segment with basal half black, with two red marks; yellow bands on segments 1 to 5 broadly interrupted by red in the middle; sixth segment with a short bilobed yellow band; apical plate very hairy. The antennæ remind one of *N. pascoensis*, but the insect is otherwise very different.

Nomada alpha, new species.

One ♀ taken by F. C. Bishopp, marked Fort Collins, May 20, 1903, Colorado. Taken from flowers of *Capsella bursa-pastoris*.

Length about 8½ mm.; head and thorax red, with black and yellow markings; abdomen red and yellow. Front depressed, coarsely an d

closely punctured; facial quadrangle much broader than long; mandibles very shiny, pale reddish with black tips and more or less yellow bases; labrum, clypeus, and sides of face on each side of clypeus, yellow, the yellow not sharply defined from the red just above; ocelli on a black patch, connected with a black patch on front, but leaving a red mark in front of middle ocellus; frontal patch sending black bands to sides of clypeus, these and the narrowly blackened upper clypeal suture making a large A; posterior orbital margins very broadly red, with a large yellow stripe on the lower two-thirds; antennæ long, red without any black, scape yellowish in front; third joint longer than fourth; mesothorax coarsely rugoso-punctate, red with three rather ill-defined black stripes; prothorax black, with its upper border, and the tubercles, yellow; pleura red, with a black spot beneath; a broad black band from wings to middle and hind coxæ; scutullum red suffused with yellow; postscutellum bright yellow; metathorax black, with a large red spot on each side; tegulæ red; wings yellowish, apical margin not much darker than the rest; stigma bright orange-ferruginous, nervures pale brownish; second submarginal cell moderately narrowed above; third of the narrow type; basal nervure a long distance basad of transverso-medial; legs bright red, anterior and middle femora with more or less of a yellow apical spot; hind femora wholly without black; abdomen very minutely rugoso-punctate; first segment red with a transverse yellow mark on each side; second red with very large pyriform yellow marks; third similar, but with even more yellow; fourth yellow except extreme base and apical margin: fifth yellow; venter banded with yellow and red.

In Robertson's tables this runs to *Holonomada*, but it is closely related to some of the species which are referred to *Xanthidium*.

Nomada libata, Cresson.

This is erroneously called *limbata* in Dalla Torre's Catalogue. Mr. Rehn has kindly examined Cresson's type ♂, and finds the apical plate rather narrow, deeply notched; the ventral surface of abdomen immaculate except the apical margins of the three terminal segments, which are yellow to a considerable degree; scape normal.

These characters are in part similar to those of *N. armatella*, which may be known from *libata* by the absence of yellow on venter and the basal nervure far basad of transverso-medial (in *N. libata*, *parata*, *bethunei* and *coloradensis* it is only a little basad of it).

Nomada dilucida, Cresson.

Mr. Rehn has kindly examined Cresson's type ♀, and finds it differs structurally from *N. morrisoni* thus: labrum narrower, more rectangular; scape heavier and more robust; abdomen glabrous instead of pubescent.

I am extremely indebted to Mr. Viereck, who has most kindly examined all of the types in the collection at Philadelphia, and reported on the venation and proportions of the third and fourth antennal joints.

Nomada frieseana, Cockerell and **N. semiscita,** Cockerell.

These two species were discovered at Colorado Springs since this paper was written, and described in Annals & Mag. of Nat-Hist., July 1904. *N. frieseana* is allied to *N. rubicunda*, and *N. semiscita* to *N. scitiformis*.

Veg Muskmelons

Bulletin 95. **December, 1904.**

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

EARLY CANTALOUPES.

—BY—

P. K. BLINN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1904.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

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EARLY CANTALOUPES.

BY P. K. BLINN.

One of the most important questions connected with cantaloupe growing is how to get them early, for here as elsewhere it is the "early bird that catches the worm." The high prices received for the first cantaloupes on the market offer great reward to the grower who is successful in maturing his crop a few days in advance of his neighbors.

It is not uncommon in the vicinity of Rocky Ford for the extra early cantaloupe field to return to the grower from two to three hundred dollars per acre, and it is in hope of such returns that every grower plants his seed; but as the season advances it soon becomes evident that from one cause or another many have fallen behind in the race, and only those who are fortunate enough to escape the various adverse conditions which beset the crop from time to time and check its growth, succeed in getting the early crates.

Some of the many factors that influence the development of a crop of cantaloupes are beyond the control of the farmer, but this bulletin is planned to deal with the elements that can be influenced by him, not with a view to giving specific rules which will insure an early crop, for the varied conditions of different farms and seasons make explicit directions of little value; but to present from observation and experience such facts as may reveal to some extent the underlying principles to be considered in producing a crop of cantaloupes.

Seed.—The Netted Gem cantaloupe is virtually the only variety grown in the cantaloupe growing sections of Colorado, yet there is almost a variety variation in some of the strains of seed from different growers, due to varying lines of selection. It is generally conceded that the most perfectly developed types are not quite so apt to be early as the cantaloupe grown from "slickers" or culls; but the ultimate value of a good melon and its influence on the market make it imperative for the grower to plant nothing but the best seed, of ideal type and quality, with early tendencies. It is evident from numerous comparative observations that the question of seed does not have so much influence in producing

early cantaloupes as does the care and cultivation in handling the crop.

Soil.—Experience has proven that a sandy loam is the soil best suited for cantaloupes, and that its condition of tilth and the available fertility are the prime essentials in bringing cantaloupes to quick maturity.

The secret of getting soil in that ashy, mellow condition so desirable for cantaloupes is largely one of experience, for hardly two farms can be handled the same. In general, there must be moisture in the soil over winter to get the disintegrating effect of frost, and plowing should not be done until the ground is dry enough to pulverize mellow. Barnyard manure has long been the means of supplying fertility to force cantaloupes to early maturity; but owing to the limit of its supply, crop rotation became necessary, and in 1896 the Sub-Experiment Station at Rocky Ford made the first test of cantaloupes on alfalfa sod, which resulted in signal success, demonstrating that alfalfa sod affords ideal soil conditions for cantaloupes both in early production and in securing a big yield. The test was on a plat of one acre, which was planted May 4th in hills six feet each way and received ordinary care; the plat having three hoeings, four cultivations and seven irrigations during the season. The first crate of ripe cantaloupes was marketed July 29th, only one day later than the earliest record ever made at Rocky Ford with cantaloupes on well manured ground. The vines made a remarkably uniform growth and the yield was three hundred and fifty standard crates per acre, nearly double the normal yield on ordinary soil. Since then alfalfa sod has been in general use for cantaloupes in the crop rotations of the Arkansas Valley.

Its relative value over old, worn-out land is well contrasted in Plate 1, which is a photo taken July 7th on the farm of I. D. Hale; the rows on the right were planted on alfalfa sod at the same time and had the same care as the balance of the field.

The same contrast is often seen in land that has been growing beets and that which has not, the beet ground being unfavorable for early cantaloupes; indeed, experience of four years at Rocky Ford since the introduction of the beet crop testifies that it is useless to expect early cantaloupes on beet ground, although if the land is not too much exhausted, very satisfactory late cantaloupes have been grown after beets.

During the season of 1904 several commercial fertilizers have been tried extensively to supply the needed elements for growing early cantaloupes on beet ground, but the results are so conflicting that a conclusion is not warranted, except that the use of the fertilizer in and under the hill at planting time is extremely hazardous.

PLATE 1.

PLATE 2. COLO. AG. EXP. STA.

PLATE I.—Cantaloupes at right grown after alfalfa. At left on worn out soil.

PLATE II.—Root System of Cantaloupe Seedlings.

PLATE 3.

PLATE 4. COLO. AG. EXP. STA.

PLATE III.—Showing Development of Cantaloupes. Photo taken July 2, 1904.

PLATE IV.—Same Field Two Weeks Later.

Hardly a grower who used the special melon fertilizers according to directions, but lost from a few rows to many acres of early cantaloupes. The little melon plants died when the roots came in contact with the caustic elements of the fertilizer. A few growers had encouraging results; and when the manner of applying and the quantity to be used in relation to irrigated conditions is determined by careful experiments, the use of commercial fertilizers may result in valuable profits to the melon growers, but until then, barnyard manure and rotation with alfalfa and other leguminous crops offer the safest and most reliable source of fertility.

Care and Cultivation.—If there is a secret in getting early cantaloupes it is in growing the crop from start to finish with a uniform unchecked growth; the cantaloupe does not seem to have the power to rally from a check in growth or an injury from an insect and still make its normal development. The back-set not only cuts off the production of early cantaloupes but seriously affects the size and quality of the melon. There are numerous instances where unfavorable conditions of growth have produced a large quantity of pony melons, while under more favorably growing conditions the same seed and soil have yielded standard sized cantaloupes. One of the first signs of promise for early cantaloupes is a quick germination and rapid development of large cotyledons. Seed that germinates slowly with small yellow appearing seed leaves has never made early cantaloupes.

Planting.—The first requisite aside from moisture for a good start is warm weather, as cantaloupe seed cannot germinate when the ground is cold and freezing; and if perchance the days are warm enough to germinate the seed that is planted in March or April, the cold nights that are sure to follow will offset the advantage of early planting.

Fifteen years of weather records at the Sub-Station in Rocky Ford reveal the fact that in nine out of the fifteen years there has been frost the last few days of April or the first in May that seriously injured or completely killed any melons that were germinated at that time, and that light frosts and cold nights are common up to the middle of May. Old cantaloupe growers around Rocky Ford consider that May first is plenty early to plant cantaloupe seed.

The seedling period is the critical time in the development of a crop of cantaloupes. It is in that stage that it usually receives a check in growth from cold weather, high winds or lack of moisture. It is also at this time that the striped cucumber beetle makes its destructive attacks. A knowledge of the growth and root development of the seedling will in a measure help to explain the reason for the steps taken and the precaution necessary in handling the crop during this important period.

Plate 2 represents two cantaloupe seedlings, the one on the right revealing the plan of the first root system that develops when the seed germinates; it penetrates almost directly down from the seed while the stem is pushing its way to the surface. These roots seem to form a temporary support for the plant during the first two or three weeks, for up to that time the stem from the seed point up to the surface of the ground is smooth and white, with no evidence of the lateral roots which are shown on the stem of the seedling to the left. The second root system develops from the stem about the time the fifth leaf appears, or four or five weeks after germination; these roots seem to form the main feeders which develop the plant, for the growth of a hill of melons is practically insignificant until it feels the impulse of this larger and better root system. The question of early cantaloupes almost hinges on the success of the farmer in supplying conditions that will favor early development of the lateral root system.

It seems evident that the depth of planting and the manner of managing the soil in the hill has an important relation to the early development of these lateral roots. Experience teaches that seed planted much over two inches in depth are slow and difficult to germinate, being weakened by the long stem that is necessary to reach the surface, and on the other hand if planting is too shallow, the seed are apt to dry out, or if rain follows a crust will form which must be removed, and that often exposes the seed with fatal results, or leaves the plant with too shallow a stem support. It is then whipped and wrung by the high, dry winds, or the long stem is exposed to the attacks of the cucumber beetle.

Seed will germinate readily when weather conditions are favorable, if planted at about the depth indicated by the white portion of the stem of the seedling at the left in Plate 2. When the seed leaves are nearly to the surface, if a garden rake is drawn through the hills with a lifting motion it will remove any crust or dry lumps which obstruct the little melon plants.

Plenty of seed should be used to provide against loss in handling the hills or from attacks by insects; it also affords a chance to select the thriftiest specimens when the thinning is made to two or three plants. Owing to the injuries from the striped cucumber beetle, this thinning should not be done until the plant gets several leaves and the lateral roots are developed; the extra plants in the hill should be destroyed by pinching or cutting the stem, as pulling is apt to disturb the remaining plants.

The best known precautions against the cucumber beetle consists in the application of lime, ashes or road dust, and the continual working of the field with hoe or cultivator.

Hoeing.—Hoeing the hills is of great importance, but it should be done with skill both as to the time and the way it is

done, for careless hoeing is a common error; if the seed has been properly planted in mellow soil and the irrigation properly applied, there is no reason for deep hoeing in and close to the hill, as it only disturbs the plants and dries out the soil; weeds can be destroyed by shallow hoeing.

The dry, cloddy soil on the surface should be removed from the hill by hand and replaced with fine, moist, mellow soil, hilling up the plants as far as possible, which will protect the plants from wind and insects in a large measure; but the most important feature of this process is the holding of the moisture well upon the neck or stem and affording the best conditions for a long base and an early growth of the main root system. If, on the other hand, the soil in the hill is loosened up with the hoe and only hilled up by drawing the loosened soil to the plant with the hoe, the hill will usually dry out, and only a short portion of the stem be in moist soil, consequently it has but a short base for the production of its root system.

Cultivation.—A thorough preparation of the soil before it is planted to cantaloupes will very much lessen the necessity for so much cultivating afterwards, but a great deal depends on frequent and thorough cultivation during the early stages in the growth of cantaloupes; at first it should be deep and thorough, but not close enough to disturb the plants; the cultivations should be more shallow and further from the hills as the plants develop. The grower who cultivates deep and close to the hill because the vines do not prevent him, is cutting off one source of early cantaloupes. He should study the growth of the roots, for they form the counterpart of the vines on the surface, only they ramify the soil more thoroughly and to a greater distance than the length of the vines. Plates 3 and 4 will give a conception of the root system which must exist to produce such an increase of growth in so short a time; the first was taken July 2, 1904, and represents the growth of about eight weeks, while the second was taken at the same point two weeks later.

Irrigation.—Moisture for the cantaloupe hill is generally supplied by the irrigation furrow. It should always reach the seed or plant by soaking through the soil. Irrigation should never be allowed to over-soak or flood the ground, as the soil will then become hard and not permit a good growth.

The relation of irrigation to an early set of cantaloupes is a somewhat mooted question. There are growers who argue the use of frequent irrigations during the setting period to secure a good set, and there are others who prefer to keep the vines rather dry and even letting them show the need of water before they will irrigate during the setting stage.

There have been results that seemed to support both theories,

yet close observation would not warrant following either plan to an extreme, but rather a medium course of supplying enough moisture for an even, healthy growth, which seems to be the essential condition all the way through. An excess of irrigation during the hot weather in July will doubtless tend to grow vines at the expense of early fruit; but the most disastrous result of too much water—having the ground so soaked that the surface is nearly all wet, and affording the moist, dewey condition which is favorable to its development—is in the development of rust.

The rust problem is a serious one in cantaloupe culture in Colorado. Controlling it by proper application of irrigation is only a palliative measure, yet a marked contrast is often seen in two portions of a field; one over-irrigated, and the other comparatively dry, aside from the moisture necessary to the growth of the vines. Rainy weather and dewey nights afford the proper conditions for the growth of the rust spore, and while the farmer cannot change climatic conditions, yet by careful attention in the application of water, having the rows well ditched, and with adequate waste laterals to prevent over-soaking and flooding, the surface of the ground will dry rapidly after a rain or an irrigation. Thus the dews at night will be less, and in a measure alleviate the effects of rust.

Marketing.—The high prices which prevail at the beginning of the season, and the urgency of the commission men, have resulted in the shipment of many green and unmarketable melons. It is evident that a continuation of such practice will produce dissatisfied customers and consequently loss of trade. The popularity of the Rocky Ford cantaloupe and its value as a money making crop, should induce the farmers of the Arkansas Valley to maintain the standard of excellence by every means in their power, and to discountenance the shipping of green and otherwise unmarketable melons as an act of treachery to the cantaloupe industry.

Bulletin 96. **February, 1905.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

The Shade Trees of Denver.

—BY—

W. PADDOCK and B. O. LONGYEAR.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1905

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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THE SHADE TREES OF DENVER.

By W. Paddock and B. O. Longyear.

A great many shade trees have been planted on the farms and in the towns in the agricultural sections of Colorado, but this does not necessarily mean that all who have planted trees did so because of their love of plant life. Perhaps a majority of the settlers formerly lived where trees grow to perfection and their absence here emphasized the fact that a house destitute of trees does not meet all the requirements of a home. Then, too, it is almost necessary to have some relief from the glare of the intense sunshine and from the monotony of the plains. So the settlers have not been slow to make the best of what the country affords and but few country homes are seen in the older agricultural sections that are not surrounded by groves of cottonwood or boxelders. Neither is it uncommon to see country roads bordered with these trees; and in the older towns and cities, shade trees are as common as in many states that are more favored in this respect. Associated as they are with the early development of the state, the cottonwood and boxelder will not soon be supplanted. Their principal virtues, however, lie in the fact that they are easily transplanted and under favorable conditions make rapid growth. They also withstand the extremes of drouth and moisture if not too long continued and do not readily break down during a windstorm or under a load of snow and sleet. But, unfortunately, the quick growth for which these trees are mostly esteemed, leads naturally to early maturity. Trees that were planted by the first settlers twenty-five and thirty years ago, are now mature, and, judging from appearances, it will be only a few years before most of them must be removed. Full grown specimens of either species are rarely beautiful, and the wood has little value from a commercial standpoint.

Still another cause has contributed in no small degree to the popularity of these trees. Large sums of money have been expended in the effort to introduce trees from the East, especially those kinds that were common about the old homes. But as the conditions that obtain in an arid climate were little understood, and a majority of the people who undertook to plant trees were not accustomed to the work, most of these efforts resulted in failure, since but few trees will stand abuse and neglect so well as the cotton-

wood and the boxelder. Is it any wonder then that the idea has been almost universal that trees foreign to the state will not succeed?

But in a large city like Denver, with its parks, cemeteries, avenues, and fine residences, fine trees are such a necessity that failures only stimulated the desire to overcome the obstacles. Repeated trials have resulted in many successes, and as a result there are growing in that city today at least 60 species and varieties of trees which are foreign to the state. Many of these trees occur as isolated specimens, and as they are scattered over a large area they have attracted but little attention. A majority of the residents of Denver will no doubt be surprised to learn of the large variety of trees in their city. Mr. W. G. M. Stone, President of the State Forestry Association, has given much attention to the trees of Denver for several years past, and we are indebted to him for all the data given in this bulletin. Mr. Stone read a paper at the convention of the Board of Horticulture in 1901 in which the following extract occurs: "Whatever trees are found to grow successfully in Denver would thrive at all other points in the state adapted to deciduous tree culture." Believing that this statement is true in the main, it is then desirable that all prospective tree planters should have the advantage of this experience. To be sure, a record of 25 or 30 years' growth is not conclusive evidence as to the final estimate that should be placed on an apparently desirable tree. More especially is this true where data can be secured on only a few trees of a kind; but any experience that will be an indication as to what varieties may succeed must be productive of much good.

These few pages are then intended for those people who are desirous of adorning their grounds with fine trees, and who are thinking of the future as well as for immediate effects.

Most people make the mistake of planting trees just as they receive them from the nursery. It should be remembered, however, that in digging, a large portion of the root system is left in the ground, consequently when trees are planted without cutting the tops back to correspond with the loss of roots many of them die or make an unsatisfactory growth. It may be stated as a general rule that all trees and shrubs, except the conifers, should have a large portion of the tops removed when they are transplanted. All bruised roots should also be cut off with a sharp knife so as to leave a smooth surface which will readily heal.

The use of large trees should generally be avoided, as vigorous young trees, two to four years old, will usually give much the best results. Large trees can be successfully transplanted if a large ball of earth is taken up with the roots, but this is an expensive operation and is rarely carefully done. Where this precaution is not taken the older trees seldom make satisfactory growth and many of them soon fail.

The best time for planting trees in Colorado is in the spring of the year. This is true for the reason that the winds of winter are apt to dry out the trees as well as the soil. The root system not being established, cannot supply the moisture lost by evaporation, therefore the plants die.

Shade trees respond to cultivation and care as well as do other plants. While many trees will make a fair growth in poor soil, yet the best soil will be found none too good. The hole in which the tree is to be planted should be large enough to allow all the roots being spread out naturally, and of sufficient depth to admit of the tree's being set one or two inches deeper than it stood in the nursery. If the soil at the bottom of the hole is hard and uncongenial some of it should be removed and be replaced with a generous layer of loose top soil. After the tree has been placed in the hole and its roots properly spread out, the soil should be filled in a little at a time and firmly tamped around the roots so that no cavities can be formed.

As soon as the tree is planted water should be turned on until the ground is thoroughly moist. Especial pains should be taken during the first summer to see that the ground around the tree does not become dry; neither should it be kept too wet. Later in the season less water should be given so that the trees may ripen their growth for winter, as it too often happens that the foliage is frozen from the trees instead of ripening naturally as is indicated by autumn tints. The injudicious use of water late in the season is undoubtedly the direct cause of much of the winter killing of trees.

On the other hand, care should be taken that the ground does not become dry during the winter. If sufficient moisture is not present in the soil to replace that which is lost by transpiration from the branches the tops "freeze dry." In most soils trees will be benefited by a watering in the latter part of November or the early part of December. The necessity of subsequent irrigations will depend upon the weather conditions, but close watch should be kept through the winter to see that the ground does not become too dry.

The amount of damage that is done to shade trees by careless and aimless pruning is difficult to estimate, but the results are to be seen on every hand. With the advent of spring the mania for "cleaning up" comes on and the trees are often the first objects to be attacked. One reason for this no doubt is that a large showing for one's labor can be made in a short time.

People who attempt to prune trees ordinarily have one of two ideas in mind. The more common idea, perhaps, is that the branches of all trees should be removed from the lower two thirds of the trunk. The result is a stiff, bare trunk with a few branches at the top—the ungainly remains of what might otherwise have been a beautiful tree.

The other idea is that when trees have nearly or quite completed their growth the tops should be cut back—regardless of the size of the trunk or branches. Some trees, like the cottonwood, will stand such abuse fairly well, but they are mutilated for the rest of their lives. Fortunately many kinds of trees do not live long after such heroic treatment.

Although shade trees usually need but little pruning, that which is needed should be done systematically, and the natural shape of the tree should always be borne in mind. Specimen trees should as a rule never be pruned except when they are planted, as mentioned above, and as occasional sprawling branches or bad forks are likely to be formed. Street trees likewise need but little pruning except that the head should usually be started about ten feet above the surface of the ground. In any case each tree should be allowed to assume its natural form as much as possible.

Another mistake which is commonly made is that of planting trees too close together. One is naturally desirous of securing quick effects; and as a means of securing this end close planting is commendable, providing the surplus trees are removed as soon as they begin to crowd. But this appears to be a difficult matter for the average person to do.

In some towns double rows of cottonwood trees, the trees ten feet apart in the row, may be seen, one on each side of the side walk. The result is a thicket of ungainly trees which serve no purpose that would not have been gained had there been but one row and the trees placed three or four times as far apart.

The majority of trees on most streets should be planted 40 feet apart. Then if quick effects are desirable, the rapid growing Carolina poplar may be planted temporarily between the slower growing kinds, thus making the trees 20 feet apart. The temporary trees should be removed at the first sign of crowding and those that remain will soon fill in the gaps.

Most of the trees here mentioned are propagated ordinarily by seeds, a few by cuttings and layers, while some, as the elms, basswood, catalpa and black walnut, sprout readily from the stump. If one strong shoot is allowed to grow a new tree may be secured in a comparatively short time in this way. Seeds of most trees ripen in autumn and may be planted then where they are to grow, or they may be stratified and planted in spring. Stratification consists of mixing the seeds with moist sand, or alternate layers of seeds and sand which may be placed in barrels or boxes and kept out doors. The alternate freezing and thawing to which they are subjected during the winter, when thus exposed, is necessary to enable the seeds of many trees to germinate.

A tentative list is given below of the kinds of trees which are foreign to the state that are known to be growing in Denver:

Elm, American
" Cork
" Red
" Scotch

Ash, Blue
" Green
" White
" European
" Weeping

Mountain Ash,
" " Oak Leaved
" " Weeping

Locust, Black
" Clammy
" Honey
" Honey Thornless

Maple, Soft
" Sugar
" Norway
" Sycamore
" Wiers Cut Leaf
" Japan

Black Walnut
Butternut
Horse Chestnut
Buckeye
Catalpa (Speciosa)
" (Bignonioides)
Linden, American
" European

Birch, White
" Black
" Weeping

Oak, Red
" Burr
" White
" Swamp
" English
" Pin

Willow, Weeping American
" Weeping European
" Laurel Leaf

Poplar, Carolina
" Lombardy
" Silver Leaf
" Siberian

Tulip, or Yellow Poplar
Chestnut, Sweet
Mulberry, Red
" Russian
" White

Sycamore
Hawthorn, sp.
Hackberry
Cherry, Black, of commerce
Kentucky Coffee Tree
Russian Olive
Ailanthus
Red Bud
Persimmon
Cucumber Tree

Many of these kinds have not been tested long enough to warrant further notice at this time, and not a few must eventually prove to be unsuited to our conditions. A few of the more promising kinds, those that now show every indication of being of permanent value, have been selected for description and illustration:

AMERICAN ELM.

(*Ulmus Americana* L)

Few trees equal and probably none surpass the American elm for street planting in the Northeastern States, and trials have shown it to be one of the most desirable trees for this purpose in Colorado. There are several recognized forms or types of this tree, the commonest being the vase shaped type. This is specially suited to avenue planting, as the trunk divides some distance above the ground into numerous branches which gradually spread toward the tip and, as the tree acquires age, become more or less arched, thus producing that pleasing effect so noticeable in elm avenues of long standing.

While pre-eminently an avenue tree, this elm is equally suited for planting about the home and in parks and public grounds. The top is usually carried high above the ground, especially when grown among other trees, thus furnishing shade without impeding free circulation of air.

The airy grace and majestic bearing of the elm when well grown, likewise make it a most desirable tree to plant where generous artistic effects are desired. It is a rapid growing tree when young and also long-lived, qualities which are not often found in the same species. While this tree does best in a rich, moist soil, it is adapted to a variety of situations and soils where water can be supplied. Its wood is tough and hard to split qualities which enable it to withstand severe winds and storms.

It occasionally happens that sleet storms load the tops with ice to such an extent that the more upright branches are broken down. This trouble is no more liable to occur in this state, however, than in other portions of the country where the elm is grown, and in most cases the trees are capable of making a rapid recovery after the damaged branches are removed, owing to their ability to push out new shoots.

Young trees of this species sometimes show a straggling habit of growth which can be usually corrected by a little judicious pruning. As with most trees the elm does best and makes the most perfect specimens when planted young and when the least amount of root pruning is necessary.

Several other forms of elms can be seen in the city among which may be mentioned the cork, Scotch and English elms. All of these kinds appear to be desirable and some of them may prove to be better adapted to our conditions than the common white elm.

The various kinds of elms are commonly propagated by seeds which usually ripen in May or June. The seeds should be sown at once and the most of them will soon germinate, but a few may remain dormant until the next spring.

Many insects attack the elm, among which the elm leaf beetle has been quite destructive. None of these pests have appeared, as yet, in Colorado.

ASH.

(*Fraxinus sp.*)

There are three species of this tree which closely resemble each other, and any one of which may be meant when the name ash is used for those grown in this state. They are the white, the green and the red ash. Probably in most cases the green ash is the one oftenest seen and is the one most highly recommended by writers on the subject of trees for prairie planting. The ash is one of our most reliable trees for ornamental planting in this state and is capable of making a good showing in any situation where the cottonwood can be grown. It is a rapid grower, producing a somewhat rounded head of clean, dark green foliage, which assumes a bright yellow tint in autumn. Its leaves are compound, each being composed of five to nine leaflets arranged along a common stalk, thus resembling quite closely those of the walnut. Thus its foliage contrasts well with trees having large simple leaves and they are also pleasing when seen in mass.

The ash is well adapted to streets and other places where more exacting trees would fail. Thus it is hardy, its wood is tough and not easily broken down by storms and the tree is moreover capable of withstanding drouth to a considerable extent. It is especially suitable for prairie plantings for wind breaks and for shade. It can be easily grown from seeds which should be mixed with sand and kept in a shed or they may be spread on bare ground in the fall and covered with boxes or boards. In the spring the seeds should be planted in rows in a seed bed somewhat sheltered from wind and full sunlight and supplied with water.

A few years ago borers attacked the ash trees of Denver in alarming numbers and it was feared for a time that all of these trees would be destroyed. But the result has not been so serious as was anticipated, and today the insects are not as numerous as they were three years ago.

HONEY LOCUST.

(*Gleditschia triacanthos* L.)

The honey locust is a tree which has been favorably known for a number of years in the Middle Western States, where it is quite extensively

planted as a street tree and for wind breaks and hedges. It is readily distinguished from the common black locust by its smoother bark, the presence of large branched spines on the trunk and branches, and by its leaves, which are twice compound. The pods also differ from those of the black locust, being much larger and having a twisted shape. A thornless variety of the honey locust occurs which is especially desirable where the presence of spines is objectionable.

The form of this tree is quite variable, being rather broad and low in open situations, but running up pretty well when grown among other trees. It is a graceful tree, the small leaflets closely arranged, giving its foliage an unusually delicate appearance especially when contrasted with that of other trees.

The honey locust, while not quite hardy in the northern parts of Colorado, is capable of making a good growth in most sections of the state and is capable of enduring considerable drouth. The wood is hard and strong besides being very durable, moreover it is not subject to the attacks of borers, so often destructive to the black locust.

This tree is readily grown from seeds which should be collected in the fall and kept dry until spring. The seeds are so hard that they are not apt to germinate the first season unless they are first scalded with hot water just previous to planting. This treatment, if sufficiently thorough, causes them to swell, after which they should be planted at once in a well prepared seed bed. The seedlings should receive some protection during the first winter by either heavy mulching or laying down.

BLACK LOCUST, YELLOW LOCUST.

(*Robinia pseudacacia* L.)

The common locust possesses many of the most desirable qualities as a utility tree for the state of Colorado, since it is readily propagated by seeds and root cuttings, is a rapid grower, resists drought well and is hardy. The wood, moreover, is hard, heavy, of good fuel value and resists decay to a remarkable degree. In thick plantations this tree makes a single trunk of slender growth, suitable for fence and telephone posts and may in time reach a sufficient size to furnish material for railroad ties.

This locust is also much grown as a shade and ornamental tree. Its foliage possesses a delicate texture due to the small size of its leaflets and when in bloom the tree presents a very attractive appearance and gives off a most delicious fragrance. When grown in open places the trunk does not often run up far before dividing several times, in which respect it resembles the elm. The smaller branches are beset with stiff prickers which occur in pairs at the base of each leaf stalk, thus making it an unpleasant subject to handle, but, like the honey locust, smooth forms also occur. This tree frequently sprouts, especially when the roots are injured in any way, and when cut the stump sends up strong shoots.

The most serious drawback to the growing of the black locust in the Eastern States is the fact that this tree is especially subject to the attacks of borers which, while they do not at once kill the tree, yet cause great injury to it. Moreover the wood is so perforated by these pests that the trunk is often rendered practically worthless. While these enemies of the locust have not yet appeared to trouble this tree in places where it is now growing in this state, it is possible that in time they may be found, especially if the tree becomes common. But before this does occur it is probable that locust plantations may be grown to sufficient size to make them paying investments.

The tree is usually grown from seeds, which should be treated the same as those of the honey locust.

SUGAR MAPLE. HARD MAPLE.

(*Acer Saccharum* Marsh.)

It is doubtful if any tree is held in greater esteem than the sugar maple by those who are familiar with the tree as it occurs in the hard wood

portions of the Northeastern States. The maple grove has always been a favorite place wherever it exists, for a local celebration, the family picnic or a quiet stroll. And surely it is difficult to find a pleasanter spot, whether it be in the early spring when the sugar season is on, during the heat of summer, shut off by the dense foliage, or when the glorious tints of autumn are glowing in unrivaled shades of yellow and crimson from the dying leaves.

Being a rather slow growing tree, it is also enduring when favorably situated. In its typical form it is a round or oval headed tree if grown in sufficient room, but specimens occur which possess a tendency to stretch upward, like the one shown in the picture. The foliage of the sugar maple is usually quite dense and clean, making it one of the most desirable trees where strong shade and freedom from litter are wanted.

Its wood is hard, strong and of the highest value for fuel. "Curly" and "birdseye" maple are varieties of timber obtained from this tree and possess a high value in cabinet work. In sections where the sugar maple naturally occurs, it is one of the favorite street trees and many beautiful avenues of this tree exist. Its hardiness, freedom from litter and its beautiful display of autumn tints are qualities not excelled by any other tree in the Northern Middle States.

This tree sometimes suffers from sun scald where the trunk is exposed and in sections where there is great variation in winter temperature, and for this reason some protection is needed for the trunks especially when young. While no extensive trials have been made in growing the sugar maple in Colorado, the many desirable features of this tree make limited plantings worth while in places where the exposure is not too great and where water is available for irrigation.

The soft, or silver maple (A. Saccharinum L.) has been extensively planted in Northern Colorado towns as a shade and street tree. While many of these trees have proven satisfactory, no doubt a greater number have died, and the light colored foliage of those that are failing may be seen on all sides. This species, when growing naturally is at its best on the banks of streams where it is supplied with an abundance of moisture. The extremes of moisture that are common under irrigation, especially if the soil is heavy, appear to result in the death of the smaller roots; at any rate the lack of feeding roots on dying trees is always very noticeable and uncongenial soil conditions must be the cause of the trouble.

This experience has been so universal that we do not hesitate to condemn the use of this tree in most sections of the state.

The maples are propagated by seeds which may be sown in autumn or they may be stratified and sown in the spring. A few kinds ripen their seeds early in the season and these should be sown as soon as they are mature.

NORWAY MAPLE.

(*Acer Platanoides* L.)

In general this tree much resembles the sugar maple, but differs in its lower, more rounded head and dense foliage of a dark green color. Its compact form, clean trunk and thick foliage possess the sturdy aspect of a tree fostered in a rugged country and under the ocean's breath. In addition to these characters the Norway maple holds its foliage later than any other maple, the leaves turning a bright yellow before falling. It has proven to be a very hardy tree and capable of making a healthy growth in the city of Denver.

On account of its low, compact habit of growth, this tree is especially adapted for planting in door yards and parks and where dense shade is desired. It is also an admirable tree for streets and avenues. Some of the varieties of the Norway maple make excellent specimen trees for open situations in parks and yards. For this purpose the purplish leaved varieties may be recommended. The foliage when first put out is a bright purple color, which changes somewhat to a greenish purple as the season advances.

This tree is suitable for planting wherever the sugar maple is capable of growing, and in many cases may prove hardier than the latter. Propagation—by means of seeds sown in autumn or stratified and planted in spring.

BASSWOOD.

(*Tilia americana* L.)

The basswood is one of the most conspicuous trees in the native forests of the Middle States, where it often reaches the height of seventy feet with a trunk diameter of three feet. While possessing somewhat the aspect of the catalpa, the young basswood is lacking in the coarseness of foliage and branches so characteristic of that species and is well suited to take the place of the catalpa for shade and foliage effects. The basswood when grown in open situations assumes an oval or rounded form of pleasing proportions. The large obliquely heart-shaped leaves have the margins coarsely serrate, are of a bright green color and are arranged alternately on the rather slender branches, the latter being covered with a smooth gray bark.

The inner bark of the basswood is extremely tough and is capable of being readily split into very thin strips, which are often used, where the tree is plentiful, for binding fodder. Its wood is soft, light and almost white in color, there being scarcely any difference in this respect between the sap and the heart wood.

In spite of the fact that the timber is of low fuel value and that it decays rapidly when placed in the soil, still the great variety of uses to which the wood of this tree is put and the fact that it is a hardy and rather rapid growing tree suggests it as a desirable introduction into the timber plantation.

So far as it has been tried in this state the basswood has made a satisfactory growth and is to be recommended as a suitable street and lawn tree, especially where variety in foliage is desired. In addition to this the tree is attractive when in bloom, for the flowers, while not large, are numerous and fragrant and are capable, moreover, of furnishing a fine quality of nectar for honey bees.

The usual method of propagation of the basswood is by means of the fruit, which should be stratified in moist sand in an exposed place and planted in the seed bed the following spring. Many of them may fail to germinate the first year.

In timber plantations this tree readily propagates from the stump, which sends up numerous strong shoots, and by thinning these out new trunks of good form may be secured in a comparatively short time.

HACKBERRY.

(*Celtis occidentalis* L.)

This tree, while not as well known as it should be, is of wide range, having been found as far west as the Rocky Mountains. While in general appearance closely resembling the elm, the hackberry is capable of making a satisfactory growth wherever the elm succeeds, in many cases proving hardier than that tree. It has been used to some extent in Western Kansas and in Minnesota, where it is recorded as one of the best trees for ornamental planting.

It does not usually make as large a tree as the American elm, but is the equal of that tree in its slender gracefulness of limb, while the leaves are so similar in shape as to be readily mistaken for those of the elm.

While the hackberry is capable of making the best growth only in rich, moist soil, it is, nevertheless, able to do well in dry situations. It is well suited for street planting and is especially desirable for door yards and small grounds on account of its moderate size and pleasing appearance.

The hackberry is propagated from seeds which are found in the small, cherry-like fruit borne singly on the twigs. These may be sown in autumn or stratified until spring.

THE WESTERN, OR HARDY CATALPA.

(*Catalpa speciosa* Warder.)

A great deal has been said and written in recent years about the catalpa as a utility tree which could be readily grown to supply the great

and increasing demand for fence posts, railroad ties and telephone poles. It does indeed possess some of the most desirable qualities for such purposes, such as ready propagation by seeds, rapid growth and great durability of its wood in contact with soil. Its adaptability to different locations, however, has frequently been overestimated and in consequence plantings of this tree for its timber have sometimes proven unsatisfactory or even complete failures when attempted outside of its natural range. Thus the catalpa has proven undesirable in the more northern parts of the country on account of its liability to winter injury. But when planted in sheltered locations and in rich soil it has made a good showing and is useful as an ornamental tree for parks and dooryards, and where a variety of foliage effects is desired.

The catalpa, as shown in the illustration, is an upright growing tree with coarse twigs and large leaves. It is a showy tree when in bloom, the large clusters of whitish flowers faintly spotted with purple giving it an attractive appearance. In many places this tree has been extensively planted along streets and boulevards, but it seems poorly suited for such purposes, as it is apt to assume an ugly and ungraceful appearance, in many instances showing dead and bare limbs which the coarse foliage fails to conceal. Its most desirable use as an ornamental tree is shown when grouped among or against a background of other trees and where there is plenty of room in the foreground.

Many of the earlier attempts at growing the catalpa failed for the reason that the Eastern species (C. bignonioides) was substituted for the hardier Western kind. The former species is entirely worthless in Colorado, and too great care cannot be taken to get seeds from reliable people. Seeds should be planted in the spring in a well prepared seed bed. In some localities cuttings root easily when placed in moist soil.

BLACK WALNUT.

(*Juglans nigra* L.)

The black walnut has always held a prominent place among the most valuable native trees of North America. At one time the forests of the Middle Eastern States contained many magnificent specimens of this tree, but the high value set upon its timber led to their early removal, so at the present time it is rarely that one sees the black walnut as it grew in the primeval forest.

It is not uncommon, however, to see the black walnut used for street and roadside planting in its native range, as it is of moderately rapid growth when young, presents an attractive appearance and the nuts are highly esteemed by many persons. Plantations of this tree for its timber are apt to be somewhat disappointing on account of the fact that the wood does not assume the rich, dark brown color, which has made it so much used in cabinet work, until the trees are of great age. But before this occurs the young trees may be used for fuel and for posts, the durability of its wood making this tree one of the desirable kinds for the latter purpose.

For satisfactory results the black walnut should have a rich soil and a fairly constant water supply, under which conditions it has made an excellent growth in this state. It is particularly suited to parks and similar places, where it can have room to develop on all sides, when it assumes a rounded top of considerable density.

Its foliage slightly resembles that of the ash but is more attractive, being composed of numerous pairs of leaflets arranged on long stalks, which remain on the tree for some time after the leaflets are shed. The trees begin to bear nuts when ten to fifteen years of age.

This tree is quite readily propagated by means of the nuts, which should be gathered when mature, stratified over winter and planted in spring. Or the nuts may be planted in autumn where the trees are to stand. The black walnut does not transplant readily, when over a year old, unless the precaution has been taken to cut the long tap root while the trees were small.

THE BIRCHES.

(*Betula sp.*)

Among the birches are found some of our most graceful ornamental trees. As a group they are characterized by their slender branches and small open foliage while the bark in many species is smooth and possessed of some characteristic color. The wood of the larger kinds is much used in the manufacture of small wooden articles, while the curly grained individuals furnish valuable lumber for cabinet work.

The black birch (Betula occidentalis) is the principal native tree of this group in Colorado. It is a rather small tree, sometimes reaching a height of twenty to thirty feet, with bark of a bronze color. It is seldom planted, but is capable of being used to lend variety to ornamental tree plantings.

The European white birch (Betula alba) is a native of Europe, but has been extensively used in America as an ornamental tree, where it is becoming naturalized. It is a slender, graceful tree, reaching a height of thirty to forty feet. Its most noticeable feature is the chalk white color of the bark, on the trunks and older branches, which makes it a striking tree especially in the winter when planted in front of a group of evergreens. It is much used on this account for parks and public as well as private grounds.

The cut-leaved weeping variety of the white birch is the embodiment of delicate, airy grace and is largely used in the place of the species especially where daintiness and contrast are desired. It sometimes reaches a good size in favorable locations where moisture is unfailing, but it is not a longlived tree. In spite of this fact, however, it is one of the desirable ornamental trees for lawns and parks.

The birches may be grown from seeds sown in autumn or stratified over winter. The ornamental varieties are increased by budding and grafting on the parent species.

SYCAMORE, PLANE TREE.

(*Platanus Occidentalis* L.)

The sycamore occurs principally along streams and river bottoms in the Middle States and often grows to a very large size. In form the tree considerably resembles the cottonwood, but the branches are usually more spreading and crooked than in that species. On the branches and young trunks the bark is smooth and of a greenish white color, but is partly obscured on the old trunks and large limbs by patches of dark gray outer bark. Thus the sycamore presents a rather striking appearance when set off against a background of dark foliage. The leaves of this tree are large with several pointed lobes and a light green color, making it a suitable tree for securing a variety of foliage effects, especially where dense shade is not desired. The sycamore is sometimes known by the name of button-ball tree, from the fact that the small, seed-like fruits grow in dense globular heads about the size of a walnut and these hang on the tree over winter.

The wood of this tree is fine grained, hard and splits with difficulty. It possesses a handsome silver grain when quarter sawed and is used to some extent for interior finishing and for articles of furniture.

While the sycamore has been but little used in the Western States it is a desirable tree for streets and parks and will evidently thrive where planted in good soil and supplied with water. It is propagated by means of the seeds, which may be sown in spring in a seed bed.

THE HORSE CHESTNUT.

(*Aesculus hippocastanum* L.)

This tree is characterized by its rounded top of dense foliage, each leaf being composed of five to seven leaflets of large size which spring

from the end of the leaf stalk in a radiating manner. This formation of the leaves gives the horse chestnut a very distinctive character and makes it a desirable tree for securing a variety of foliage effects in ornamental plantings. Being a rather large coarse tree when well grown, it is not as suitable for small areas, as for parks and large grounds where generous effects are wanted.

Like the catalpa, this tree is showy when in bloom, the flowers being produced in large erect clusters and having white petals spotted with purple and yellow. The seeds are of a large size and are produced in a prickly pod about the size of a mature walnut. After the leaves are shed the tree is noticeable among others by its coarse, upright branches, each bearing large terminal buds covered with a sticky varnish.

This tree can be readily grown from the seeds, which should be collected in the autumn, buried in sand before they dry and planted in spring. Or they may be planted in a sheltered seed bed in autumn, where they are allowed to grow the next season.

The horse chestnut has been much used as a street and shade tree in the Eastern and Central States, but is not considered sufficiently hardy for Northern localities. A few trees of the horse chestnut have been planted in the city of Denver and are now sufficiently mature to produce fruit.

While this is about all the data we have regarding its suitability for Colorado, it is evident that the horse chestnut can be successfully grown in any location similar to that of Denver and where moisture and fertility are not scarce.

PLATE I.

AMERICAN ELM.—City Park. Planted about 1883; height 50 feet; circumference 54 inches. Photo Aug. 25, 1903.

PLATE II.

WHITE ASH AVENUE.—City Park. Planted about 1870; height 33 feet; circumference 30 1-3 inches. Photo Aug. 16, 1903.

PLATE III.

BLACK LOCUST AVENUE.—City Park. One tree in Denver twenty-six years old has attained a height of 60 feet, and a circumference of 71 inches.

PLATE IV

SUGAR MAPLE.—Grounds of Mrs. L. A. Howard. Planted 1883; height 33 feet; circumference 23 inches. Photo Aug. 16, 1903.

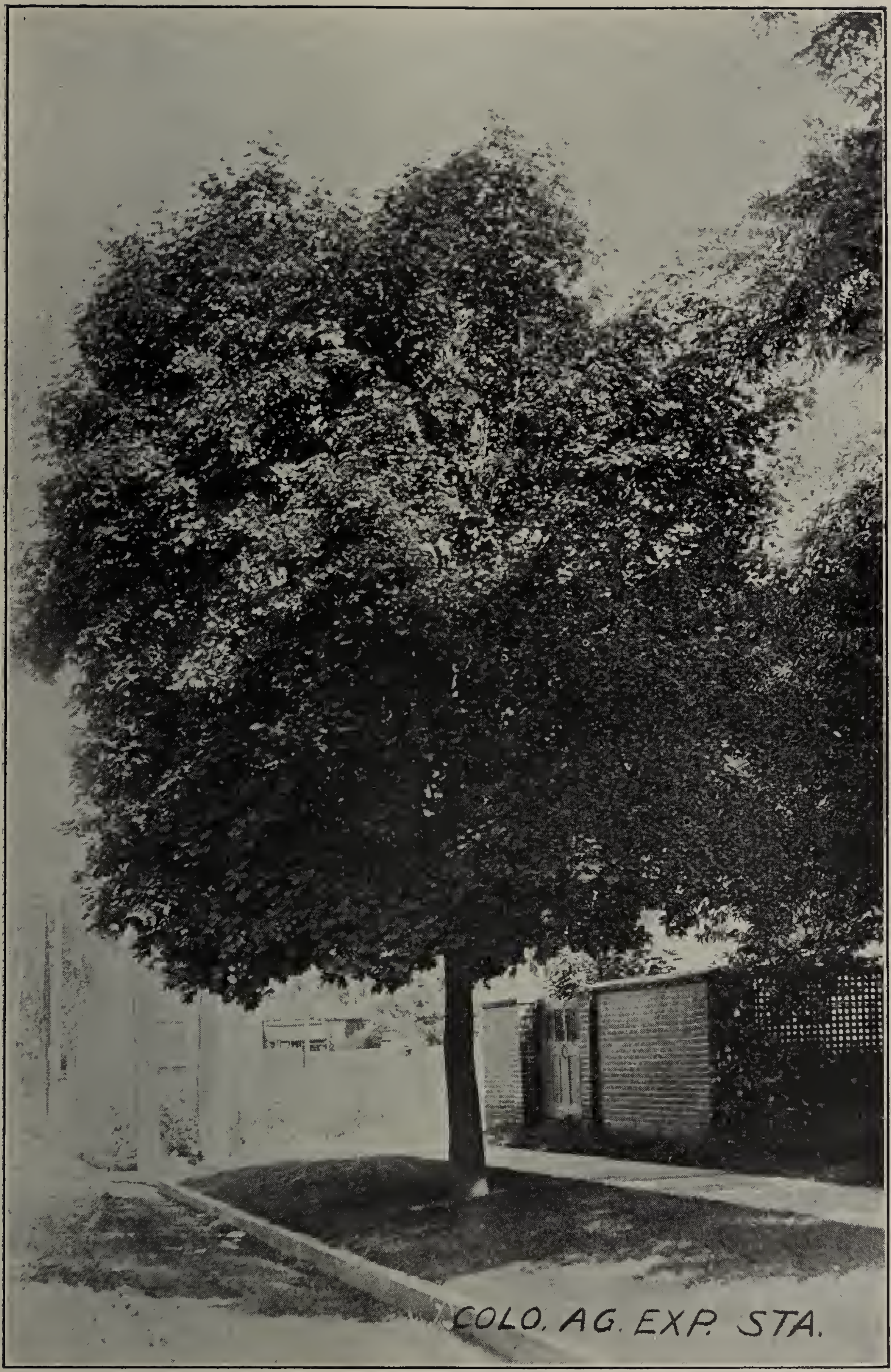


PLATE V.

NORWAY MAPLE.—Grounds of Mrs. L. A. Howard. Planted 1883; height 25 feet; circumference 25 1-2 inches. Photo Aug. 16, 1903.

PLATE VI.

AMERICAN LINDEN.—Fairmount Cemetery. Planted 1891; height 23 feet; circumference 23 inches. Photo Aug. 16, 1903.

PLATE VII.

HACKBERRY.—Fairmount Cemetery. Planted 1891; height 28 feet; circumference 26 inches. Photo Aug. 16, 1903.

PLATE VIII.

CATALPA SPECIOSA.—Campus, Agricultural College, Fort Collins. Planted 1889; height 30 feet; circumference 48 inches. Photo May, 1903.

PLATE IX.

BLACK WALNUT.—Walnut Street. Planted about 1873. Ten of the larg est have a circumference of 30 inches and over. Photo Aug. 16, 190[illegible]

PLATE X.

CUT LEAF BIRCH.—City Park. Planted about 1885; height 30 feet; circumference 18 inches. Photo Aug. 16, 1903.

PLATE XI.

ENGLISH OAK.—Fairmount Cemetery. Planted 1891; height 30 feet; circumference 31 inches. Photo Aug. 25, 1903.

PLATE XII.

SYCAMORE.—Grounds of C. B. Kountze. Planted 1880; height 37 feet; circumference 47 inches. Photo June 7, 1903.

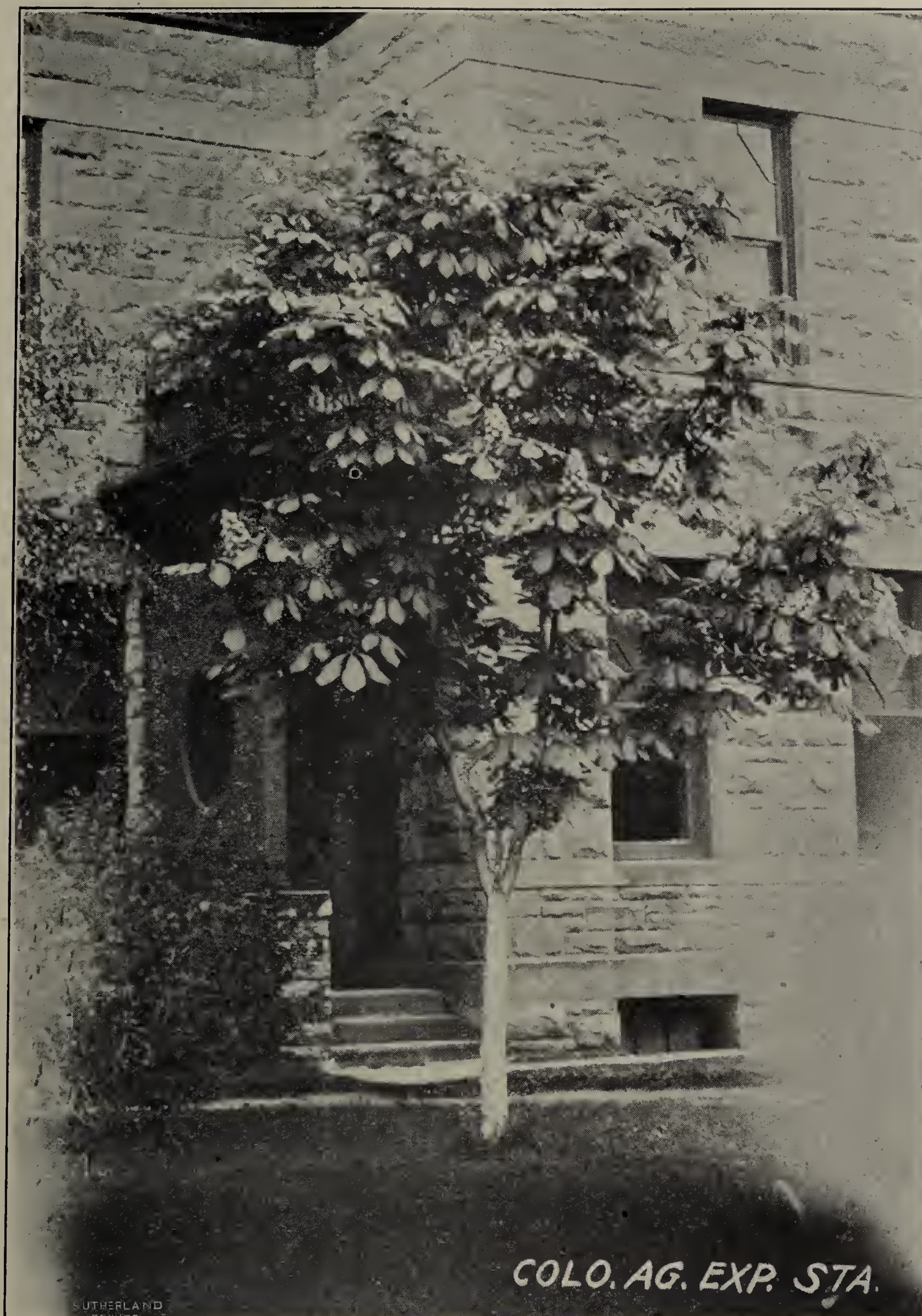


PLATE XIII.

HORSE CHESTNUT.—Grounds of W. N. Byers. Planted 1897; height 15 feet; circumference 14 inches. Photo June 7, 1903.

Bulletin 97. February, 1905

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Feeding Steers on Sugar Beet Pulp, Alfalfa Hay and Farm Grains.

By W. L. Carlyle, C. J. Griffith and A. J. Meyer.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO.
1905.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

Feeding Steers on Sugar Beet Pulp, Alfalfa Hay and Farm Grains.

By W. L. CARLYLE, C. J. GRIFFITH and A. J. MEYER.

The data presented in this bulletin is published at this tim for the benefit of cattle feeders in those sections of the country where the growing of sugar beets is coming to be a leading industry. For several years past there has been much interest manifested concerning the value of sugar beet pulp as a factor in beef production. The experiment described in the following pages was not intended to, and does not, show the actual feeding value of beet pulp. It does show, however, that this by-product has a considerable value as a feed, and may be made to play a prominent part in economical cattle feeding.

The experiment was made possible through the liberality of the Great Western Sugar Company, of Loveland, Colo., who furnished the cattle, the feed and equipment, and a part of the labor for carrying on the work. The Experiment Station greatly appreciates the kindness and the progressive spirit of Mr. C. K. Boettcher, president of the company, in thus supplying to the Station this means of testing the value of sugar beet pulp combined with alfalfa hay and farm grains as a feed for cattle.

The Station is also indebted to the U. S. Department of Agriculture, through the Bureau of Animal Industry, for financial aid in carrying on this experiment.

The results of this trial are not considered as final or conclusive, but are published in the hope that the data gathered from this initial experiment may be of some benefit to the prospective cattle feeder. Arrangements are already under way for a more complete and elaborate experiment with these feeds during the coming winter, when an effort will be made to determine the actual feeding value of sugar beet pulp as compared with other standard feeds.

The great cattle ranges of the western states have for many years supported large herds of breeding or "she" stock and have grown immense numbers of calves, yearlings, and two and three year old cattle to supply the feed lots of the Middle West, or corn belt, with feeders. Frequently this is a very profitable business for the ranchmen of the West, but at times when corn is a light crop or a partial failure, there is little demand and low prices for feeders and the ranchman must either keep his cattle until a corn crop is assured or sacrifice them at less than cost. In those sections of the West where water can be secured for irrigation purposes, ranchmen have frequently made a success of cattle feeding during the winter months. The alfalfa plant seems to have found in the irrigated sections of this western country its most congenial environment. The yield per acre is large and the quality is usually excellent owing to the fine weather that always prevails during the growing and harvesting seasons. The small grains grown in these regions are also of superb quality. The proximity of the snow capped mountains and the high altitude renders the nights rather cold and the growing season is a comparatively long one, resulting in a very heavy yield of rich and nutritious grains.

During recent years, however, the growth of the beet sugar industry has presented many new problems for solution. Prominent among these are the maintenance of the fertility of the soil, the profitable disposition of the alfalfa crop, which rotates best with the sugar beet crop, and last, and by no means least important, the proper utilization of the beet pulp, a by-product from the sugar-factories. It is estimated that at least 60 per cent. of the total weight of the beet crop, exclusive of the tops, is returned as beet pulp with practically no change in its composition except the extraction of the greater portion of the sugar content of the beet. Since many ranchmen and stockmen of the West are not familiar with the process of sugar making from beets, a few words of explanation as to what beet pulp is, and how it is secured, may be appreciated. When the beets are received at the sugar factory, they are first thoroughly washed and then carried to the slicer where they are cut into small strips about two inches long, one-fourth inch wide, and one-sixteenth inch thick, called "cossettes." They pass directly from the slicer into large tanks where running water extracts the sugar. The pulp, after the extraction process is complete, is drawn from these tanks at the bottom and transferred to a press where all the free moisture is expelled and is then transferred by means of screw carriers to a large flat pit or reservoir outside, termed the "silo." In this pit the pulp is piled ten or twelve feet deep and rapidly forms an air tight crust on the surface which preserves the lower layers per-

fectly. Any surplus water is drawn off through the drains provided and the pulp instead of deteriorating in palatability and feeding value, is actually improved in these respects after being siloed for several months. At the close of this experiment, the freshly uncovered pulp was sweet and pleasant to the taste and presented an odor almost identical with freshly pulped beets. At this time it appeared much drier than earlier in the season and the cattle appeared to be fonder of it, though they would not consume it in such large quantities. In some of the factories the pulp is carried from the building by flushing with water through elevated sluice boxes. From the past season's experience, it is apparent that this is a very objectionable practice on the part of the sugar companies and should not be followed when the pulp is desired for feeding purposes. From the six sugar factories operating in Northern Colorado during the season of 1903, there was produced at least two hundred and twenty-five thousand tons of beet pulp, all of which was available for stock feeding purposes. The area from which the beets were grown is all contained in three adjoining counties, and there were at least three hundred thousand tons of alfalfa grown in these same counties last year. These figures give some idea of the possibilities there are for successful meat production in this region.

THE OBJECT OF THE EXPERIMENT.

This experiment was undertaken for the purpose of determining:

First.—If beet pulp in combination with alfalfa hay is a suitable food for fattening steers.

Second.—If under ordinary conditions it would be profitable to feed grain in addition to the pulp and alfalfa hay.

Third.—Which grains can be fed to the greater advantage, corn or the home grown grains, barley and oats combined.

In addition to the above, it was desired to learn what effect, if any, the various rations fed would have upon the meat produced, as it was considered by many that an exclusive ration of pulp and alfalfa hay would not produce a good quality of edible meat.

PLAN OF EXPERIMENT.

In planning the experiment, it was decided that all the conditions surrounding it should be as nearly similar as possible to the practices of the cattle feeders in this section. The cattle selected for the experiment were purchased on the open market at Denver in October, and consisted of 150 head of two year old grade Shorthorn and Hereford steers. They had all been bred by one man and had been given the same care and feed from birth

until purchased. The price paid was $2.85 per hundred weight, which was low, as the cattle were a fair average lot of feeders. The entire lot of cattle were fed together on pulp and hay for several weeks prior to the beginning of the experiment for the purpose of getting them accustomed to the feed. No shelter of any kind was provided for the cattle during the entire feeding period. The hay was fed from the ground, the animals securing it by passing their heads through a rack made of poles, which prevented waste from trampling. The pulp and grain were fed from long flat boxes or "bunks" set up from the ground on legs. The enclosing and division fences were constructed of posts and barbed wire.

On December 19, the 150 head of cattle were divided as equally as possible into three groups of 50 each. General conformation, breed characteristics, as well as size and weight were made the basis for this division.

In table I is given the weights of the steers in each lot when the experiment was started, from which it may be seen that the steers were not better than a good average bunch of feeders.

TABLE I. GIVING INITIAL WEIGHT OF STEERS.

	LOT I.	LOT II.	LOT III.
Total	45,880	44,960	45,278
Average	917.6	899.2	905.6

Feeds and Feeding.—The steers in each lot were given all the alfalfa hay and beet pulp they would consume without excessive waste. In addition, Lot I was fed a light ration of ground barley and ground oats, two parts by weight of barley to one of oats. Lot II was fed the same amount of ground corn as Lot I received of barley and oats. No grain of any kind was fed to the steers in Lot III during the experiment. A large wagon scale was provided for weighing the steers each week and also for weighing the hay and beet pulp to each lot. The grain was weighed out each day, as fed, from a small platform scale.

The grain supplied was much below the average as it was purchased from time to time from the local mills and varied greatly in quality. The barley and oats were particularly noteworthy in this respect as they frequently contained a large percentage of wild oats. This was unavoidable, as we could not control the purchase of the grain. At different times as the experiment progressed, new lots of hay were purchased for each lot of cattle, so that no attempt was made at such times to keep a record of the daily consumption of hay by each lot, the total weight being charged to each lot and the average amount eaten daily and weekly calculated therefrom.

DISCUSSION OF RESULTS.

In the accompanying table is given the detailed data of the weight of steers, the amount of the different feeds consumed and the gains made by each lot in one and five week periods, and for the entire period of twenty-five weeks.

A study of the contents of this table and the summary as given in Table III, reveals some interesting features. It will be observed that after the first seven weeks of feeding, there was a marked falling off in the amount of pulp consumed by the steers in Lots I and II that were receiving grain, and that this decrease continued until the close of the experiment, while the steers in Lot III, that received no grain, continued to eat approximately the same amount of pulp throughout the experiment, until the last four weeks, when they also ate perceptibly less. The steers in each of the lots ate about the same amount of pulp for the first seven weeks of the experiment. This may be accounted for from the fact that the amount of grain received daily by each steer was so small at the beginning of the experiment that it had no appreciable effect upon the appetite for the other feeds. The steers in Lots I and II received two pounds of grain per day each, for the first two weeks, after which time this quantity was increased at the rate of one-half pound per week until they were receiving on an average six pounds each daily. This continued until the 13th week of the experiment, when they were fed seven pounds each daily for one week until the 22d week, when they had eight pounds, and from that time until the close of the experiment they had ten pounds each daily.

It is interesting to note in the case of Lots I and II receiving grain, that while the amount of pulp consumed daily diminished with an increase in the grain ration, the average daily consumption of hay remained fairly constant throughout the experiment, while there was a constant increase in the amount of hay consumed by Lot III that received no grain. It seems hardly credible that the steers in Lot III should consume approximately 60 per cent more of hay in the last five weeks of the experiment than they did in the first five weeks. Another striking feature of this table will be noted in the fact that while the amount of grain fed daily to the steers in Lots I and II was increased from week to week, there was no constant or corresponding increase in the rate of gain. Contrary to what might have been expected, there was not any appreciable increase in the rate of gain in Lots I and II with an increase in the amount of grain fed. While the average rate of gain increased somewhat after the first five-week period, when more grain was fed, yet it cannot be attributed to the increase in amount of grain fed, since the steers in Lot III that re-

TABLE II. GIVING FEEDS AND GAIN OF EACH LOT OF STEERS BY WEEKS AND IN FIVE WEEK PERIODS.

Week	FEED CONSUMED								GAIN		
	Lot I 50 Steers			Lot II 50 Steers			Lot III 50 Steers				
	Pulp	Hay	Barley & Oats	Pulp	Hay.	Corn	Pulp	Hay.	Lot I	Lot II	Lot III
	lbs	lbs	lbs	lbs	lbs	lbs	lbs.	lbs	lbs	lbs	lbs
First	58478	3693	700	57671	4288	700	58438	4037	-420	-495	-400
Second	63440	2305	700	63440	2040	700	63440	2245	305	875	875
Third	51476	3790	875	51496	3450	875	51791	3450	1615	1090	1030
Fourth	55568	3760	1050	55568	3555	1050	55568	3515	615	795	.520
Fifth	47236	4385	1225	47286	4335	1225	47236	4345	920	530	525
Total	**276198**	**17933**	**4550**	**275411**	**17668**	**4550**	**276473**	**17592**	**3035**	**2795**	**2550**
Sixth	41356	3835	1400	41666	3605	1400	41836	4430	270	780	860
Seventh	39833	3535	1575	39833	3415	1575	39833	4100	770	480	50
Eighth	34182	3329	1750	33552	3463	1750	35132	3549	1165	1035	505
Ninth	37705	3825	1925	36112	4137	1925	41090	3823	425	690	470
Tenth	36061	3825	2100	38691	4137	2100	43411	3823	1620	1700	590
Total	**189137**	**18349**	**8750**	**189854**	**18757**	**8750**	**201302**	**19725**	**4250**	**4685**	**2475**
Eleventh	35561	3825	2100	36516	4137	2100	40596	3823	1445	860	1380
Twelfth	33133	3825	2100	34295	4137	2100	42604	3 23			
Thirteenth	29755	3826	2450	31414	3901	2450	41191	4352	-645	475	755
Fourteenth	26276	3827	2800	28533	3666	2800	39777	4880	1300	1470	175
Fifteenth	21439	3827	2800	27594	3666	2800	42239	4880	920	315	510
Total	**146164**	**19130**	**12250**	**158352**	**19507**	**12250**	**206407**	**21758**	**3020**	**3020**	**2820**
Sixteenth	23555	3827	2800	25660	3666	2800	39425	4880	-150	795	415
Seventeenth	27690	3827	2800	27170	3666	2800	37460	4880	1695	930	825
Eighteenth	26670	3827	2800	26100	3666	2800	39170	4880	1630	1690	1110
Nineteenth	29170	3827	2800	29920	3666	2800	43575	4880	90	10	25
Twentieth	25025	3784	2800	28755	3826	2800	46235	4373	-930	15	-620
Total	**132110**	**19092**	**14000**	**13 605**	**18490**	**14000**	**205765**	**23893**	**2335**	**3440**	**1755**
Twenty-first	24915	3502	2800	28388	3736	2800	45351	4134	1145	900	1450
Twenty-second	22910	3700	3150	25223	4767	3150	40065	5648	955	-315	400
Twenty-third	17525	3700	3500	17995	4767	3500	34000	5648	940	1670	430
Twenty-fourth	14570	3700	3500	15115	4767	3500	32445	5648	260	320	160
Twenty-fifth	15520	3700	3500	16255	4767	3500	34345	5648	645	875	1655
Tota	**95440**	**18302**	**16800**	**102976**	**22804**	**16800**	**186206**	**26726**	**3945**	**3450**	**4095**
Grand Total	**839049**	**92806**	**56350**	**865198**	**97226**	**56350**	**1076153**	**109694**	**16585**	**17490**	**13695**

Photograph reproductions of cuts of beef from three representative steers, one from each of the lots as numbered in the reproductions.

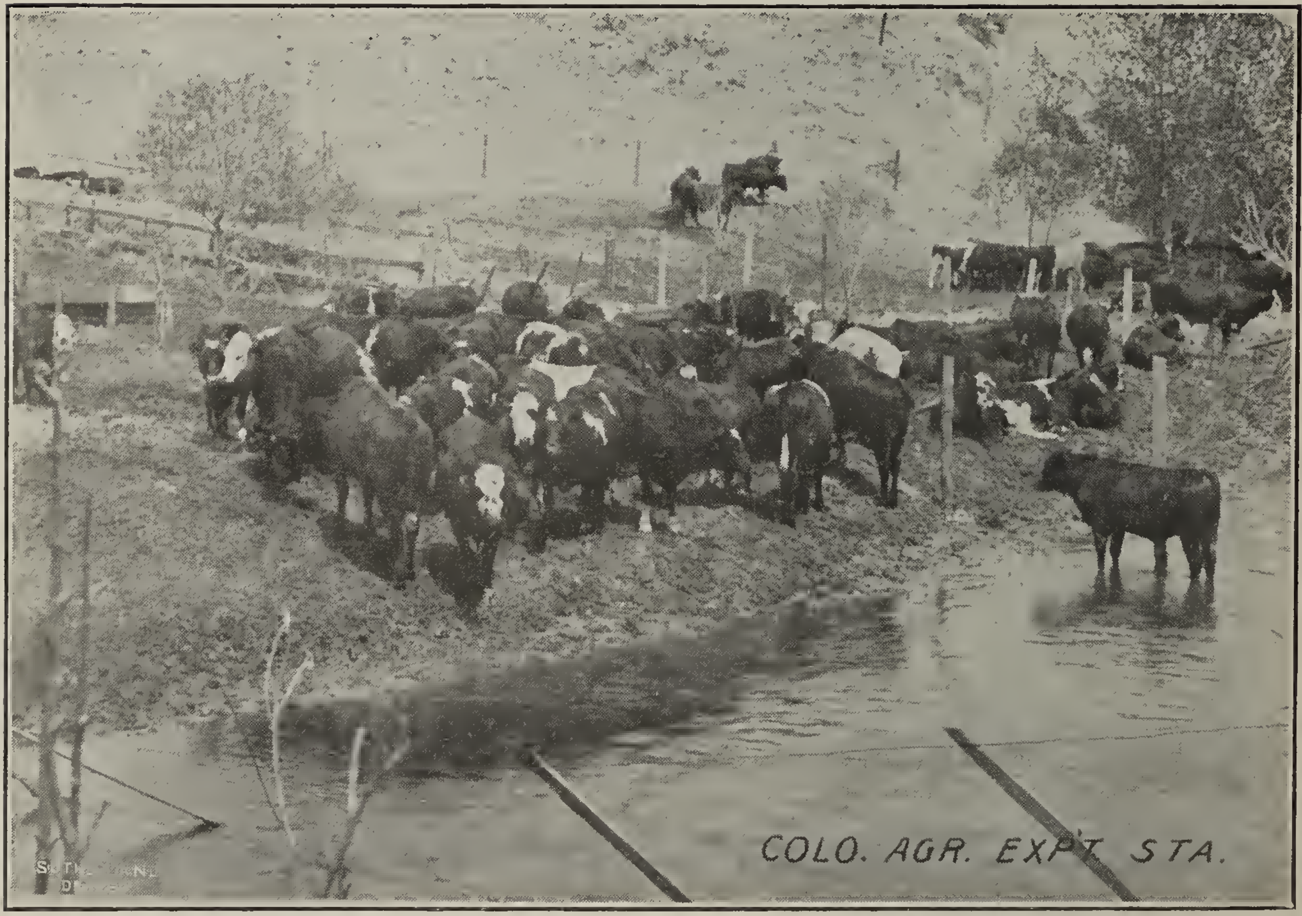
Photograph reproduction of representative steer from Lot I fed upon Alfalfa Hay, Beet Pulp, and Ground Barley and Oats.

Photograph reproduction of steers in Lot I fed upon Alfalfa Hay, Beet Pulp, and Ground Barley and Oats.

Photograph reproduction of representative steer from Lot II fed upon Alfalfa Hay, Beet Pulp and Ground Corn.

Photograph reproduction of steers in Lot II fed upon Alfalfa Hay, Beet Pulp and Ground Corn.

Photograph reproduction of representative steer from Lot III fed upon Alfalfa Hay and Beet Pulp.



Photograph reproduction of steers in Lot III fed upon Alfalfa Hay and Beet Pulp.

ceived no grain also increased in rate of gain in approximately the same proportion as did the steers in the lots receiving an increase of grain feed from week to week. So far as can be determined from the data obtained, the increase in amount of grain consumed from week to week after the first five weeks of the experiment resulted only in a slight decrease in the amount of pulp consumed and in maintaining a constant consumption of hay, while the steers receiving no grain increased in their consumption of hay.

It is difficult to understand why an average daily grain ration of 9.6 lbs. fed to a group of fifty steers, in conjunction with beet pulp and hay *ad libitum*, as was the case in the fifth five-weeks, would not result in a greater gain than an average daily grain ration of five pounds per day with pulp and hay *ad libitum*, as was the case in the second five-week period. The only conclusion that can be drawn from this data would seem to be that with an abundance of beet pulp and alfalfa hay at prevailing prices, a grain ration of five pounds of either corn or barley and oats will result in a greater gain in the early part of a feeding period than will be produced with a much larger average grain ration toward the close of such period. It should be stated, however, that the steers in all of the lots were transferred from one feed yard to another one six miles distant in the early part of the twelfth week of the experiment, which no doubt accounts in a large measure for the small gains made by all the steers during the third five-week period. Reference to Table II will show that in the case of Lot I, the 50 steers actually lost an average of approximately 13 pounds each on two weeks feed as a result of the change while the steers in Lot II made a comparatively small gain for this same period. While this transfer from one set of yards to another was absolutely necessary owing to the conditions under which the experiment was conducted, and was much to be regretted since it had such a marked effect upon the steers, yet it serves to show how exceedingly important it is to have feeding cattle remain in their accustomed environment. The result in this case on one lot of 50 steers was a direct loss of two full weeks feed and 645 pounds of live weight.

The average amount of the different kinds of feed consumed daily by each steer is shown in Table III. This data has been averaged for each five-week period and for the whole 25 weeks over which the experiment extended.

It will be seen that in the two lots of steers that were fed grain, each steer ate on the average 98 pounds of pulp and about 11 pounds of hay daily, while the steers in Lot III that had no grain, ate on the average, 123 pounds of pulp and 12.5 pounds of hay daily.

TABLE III.

AVERAGE AMOUNT IN POUNDS OF FEED CONSUMED AND GAINS MADE BY EACH STEER DAILY IN THE DIFFERENT LOTS IN FIVE WEEK PERIODS.

FIVE WEEK PERIOD	AVERAGE AMOUNT OF FEED CONSUMED.								AVERAGE GAIN		
	Lot 1.			Lot II.			Lot III.		Lot I	Lot II.	Lot III
	Pulp	Hay	Oats and Barley	Pulp	Hay.	Corn	Pulp	Hay			
First	157.8	10.2	2.6	157.4	10.1	2.6	158.0	10.1	1.73	1.60	1.46
Second	108.1	10.5	5.0	108.5	10.7	5.0	115.0	11.3	2.43	2.68	1.41
Third	83.5	10.9	7.0	90.5	11.1	7.0	118.0	12.4	1.73	1.78	1.61
Fourth	75.5	10.9	8.0	79.2	10.6	8.0	117.6	13.6	1.33	1.97	1.00
Fifth	54.5	10.5	9.6	58.8	13.0	9.6	106.4	15.3	2.55	1.97	2.54
Average for entire period	95.9	10.6	6.44	98.9	11.1	6.44	123.0	12.5	1.9	2.0	1.57

TABLE IV.

GIVING AVERAGE AMOUNT IN POUNDS OF FEED REQUIRED BY THE STEERS IN EACH LOT FOR ONE POUND OF LIVE WEIGHT GAIN.

	Pulp	Hay	Barley-Oats	Corn
Lot I	50.59	5.59	3.39	
Lot II	49.46	5.55		3.22
Lot III	78.58	8.01		

In table IV, which shows the average amount of feed required by the steers in each lot for one pound of gain in live weight, it will be noticed in the case of Lot III that seventy-eight and one-half pounds of pulp and eight pounds of alfalfa hay were required to produce one pound of live weight gain on a bunch of 50 two-year old steers. In Lot I, three and thirty-nine one hundredths pounds of barley and oats fed in the ration of this bunch of steers was equivalent to, or took the place of, twenty-seven and ninety-nine one-hundredths pounds of pulp and two and forty-two one hundredths pounds of hay. The result in Lot II was almost the same, except that it required slightly less of corn to replace approximately the same amount of pulp and hay.

The whole one hundred and fifty head of steers were disposed of to the Western Packing Company of Denver, at a flat price. The steers were weighed in the usual manner at the feed yards before shipping, and were weighed again at the yards in Denver after a short rest with hay and water supplied. In order to obtain the difference in the market value of each lot of steers as they ap-

peared when on the market, three of the leading buyers in the yards kindly consented to place a price upon each lot. It will be seen in the summary table that the steers in Lot III fed upon pulp and hay, shrank appreciably more in shipping than either of the grain fed lots. It will also be noted that the steers in Lot II fed upon ground corn in addition to the pulp and hay were valued at ten cents per hundred more than the lot fed upon barley and oats with pulp and hay, and forty-five cents more per hundred than the lot fed pulp and hay alone. It is only fair to state that the gentlemen placing a value on the steers were not informed as to the character of the feed given to any of the steers and consequently could not be even suspected of bias.

TABLE V.

GIVING SUMMARY OF DATA FOR THE AVERAGE OF THE STEERS IN EACH LOT.

	Lot I. Barley & Oats.	Lot II Corn	Lot III Pulp
Weight at beginning of experiment	917.60	899.20	905.60
Value at 3 cents per pound	$ 27.52	$ 26.98	$ 27.16
Cost of feed for entire period	$ 21.65	$ 20.68	$ 10.87
Cost of feed for 100 lbs gain	$ 6.53	$ 5.93	$ 3,79
Cost of labor involved	$ 3.50	$ 3.50	$ 3.50
Weight of finished steers at feed lot	1,249.30	1,248.00	1,189.50
Sale weight of steers	1,213.60	1,216.90	1,149.40
Shrinkage in shipping (lbs.)	35.70	31.10	40.10
Shrinkage in shipping, (per cent)	2.86	2.49	3.71
Selling price per hundred pounds	$ 5,50	$ 5.60	$ 5.15
Value at selling price	$ 66.75	$ 68.15	$ 59.19
Cost of marketing	$ 1.53	$ 1.54	$ 1.46
Net profit	$ 12.55	$15.45	$ 16.20

RESULTS OF SLAUGHTER TEST.

A very thorough slaughter test was made of each lot of steers at the packing plant, the result of which is summarized in Table VI. In this data, it will be noticed that the caul fat of the lot of steers fed upon barley and oats was noticeably heavier than either of the other lots, while the lot fed upon pulp and hay had appreciably less of internal fat than the steers fed upon corn.

Some data was collected as to the size and condition of the livers, as it was thought that this organ might indicate something of the physical condition of the animals in the different lots. From the data presented, hewever, it will be noted that there was no appreciable difference in either the size or condition of this organ in the different lots of steers.

When taken to the cooling rooms, the dressed carcasses of the different steers were carefully weighed and the weight recorded; after hanging in the cooling room for several days, the time varying somewhat with the different carcasses but no differ-

ence being made in those from the different lots, it was found that the average amount of shrinkage on each carcass of the steers in Lot I was 15.8 lbs., in Lot II, 17.1 lbs., and in Lot III, 14.6 lbs. These figures were somewhat surprising as it was expected that the carcasses of the steers that had not been fed any grain would shrink more in cooling than those fed a grain ration in addition to the pulp and hay.

TABLE VI.

GIVING DATA FROM SLAUGHTER TEST.

	Lot 1 Barley & Oats	Lot II Corn	Lot III Pulp
Average weight of caul fat	19.2 lbs	17.5 lbs	15.1 lbs
Average weight of livers	12.8 lbs	12.6 lbs	12.7 lbs
Numbers of diseased livers	4	3	2
Average shrinkage on each carcass in cooler	15.8 lbs	17.1 lbs	14.6 lbs
Average percentage of shrinkage in cooler.	2.11	2.19	2.11

Before the steers were slaughtered, a representative steer from each lot was selected by the three buyers in the yards and the carcasses of these three animals were reserved for a thorough demonstration test on the block where the various wholesale cuts could be compared with a similar cut from each of the other carcases. Photographs of these cuts were also taken and are reproduced in these pages, from which it will be seen that there was no appreciable difference in the quality or grade of the meat from each of the representative carcasses. Cooking tests were also conducted and if any choice was made by the various parties eating the meats, it was invariably in favor of that produced from pulp and hay alone. As a last and final test, a loin roast from the carcass of the steer representing the pulp and hay fed lot was served to Secretary James Wilson, of the U. S. Department of Agriculture, and a party of his friends in Denver. The Secretary, in response to a request for his opinion of this roast, wrote the following communication which needs no explanation:

"WASHINGTON, D. C., August 15, 1904.

PROF. W. L. CARLYLE,
Fort Collins, Colo.

Dear Sir:—

Replying to yours of the 6th, I have to say that I have inspected and eaten of the beef fed with alfalfa and beet pulp at the Colorado Experiment Station, Fort Collins, Colo. It was of superior quality, indicating that the Mountain states will have no difficulty in finishing cattle with their own forage plants, and making their own meats.

Yours very truly,

JAMES WILSON,
Secretary."

SUGGESTIONS TO FEEDERS.

In feeding pulp, absolute cleanliness should be observed. The pulp should be fed in troughs or "bunks" provided for the purpose. Only such an amount of pulp should be fed at one time as the cattle will clean up with reasonable waste, and the bunks should be cleaned out daily. Unless this be done, the bunks will gradually become filled with frozen pulp in cold weather, and with foul and decaying pulp during warm weather.

Pulp which has been "nosed" about and breathed upon for some time will usually be refused by the cattle. To avoid the possibility of waste on this account, and to insure profitable gains, feed often and in small quantities. It is folly to place a large quantity of pulp into the feed troughs with the intention of having a single feed last the greater part of a day. The inevitable result of such a course is to throw some of the cattle off their feed causing an unreasonable and unwarranted waste of pulp.

Pulp should never be fed late in the afternoon during cold weather. The cattle generally refuse to eat after nightfall and whatever remains in the bunks freezes before morning and occasions no little difficulty in removing it before the fresh pulp is placed before the cattle.

Pulp has a laxative tendency. On this account it is well to feed good alfalfa hay of the first cutting with the pulp where it is convenient to do so. The later cuttings of hay are more apt to encourage scouring and bloat, although where care and judgment are exercised this condition can be largely avoided regardless of which cutting of hay is used.

The feed racks for hay and bunks for pulp should be near together so that the steers will have to travel but a few steps in passing from one feed to another.

Cattle seem to be particularly fond of well-cured pulp from the silo, preferring this to fresh pulp. In order to secure the pulp in its best form, it is desirable to have it placed in the silo fresh from the factory and later transferred direct from the silo to the feeding troughs. After fermentation has once begun, exposure to the air in handling causes the pulp to deteriorate rapidly in quality. Cattle relish it less after a continual exposure to the air, and reject a larger per cent than they would in the case of pulp direct from the silo.

On account of the uniform mildness of the weather during the experiment, there was no noticeable variation in the amount of pulp eaten, or resulting gains, that could in any case be attributed to climatic conditions. It is very probable, however, that during a period of severe cold weather, pulp would prove a rather unsatisfactory feed, since it is not in any sense a heat generating food.

Bulletin 98. **March, 1905.**

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Dup under Ag Sugar Beet

Beet Worms and their Remedies

I. The Beet Web-Worm.

II. The Beet Army-Worm.

By CLARENCE P. GILLETTE.

III. Cutworms.

By S. ARTHUR JOHNSON.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO.
1905.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

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THE BEET WEB-WORM,

Loxostege sticticalis L.

CLARENCE P. GILETTE.

The beet web-worm did more or less damage in all the beet growing sections of the state last summer and fall. In the vicinity of the Loveland and the Longmont factories very little harm was done but the beets grown for the sugar factories at Rocky Ford, Sugar City, Fort Collins, Windsor, Greeley and Eaton all suffered to a considerable extent in some of the fields.

This insect does not possess any great notoriety as yet as a crop pest. Twelve years ago * last summer it attracted some attention because of its injuries to sugar beets in Nebraska during the months of July and August, and because of its injuries to a field of mint in Michigan late in September. Since 1892 it has not attracted much attention.

For thirteen years at least the moth, which is the adult form of this insect, has been abundant in the vicinity of Fort Collins, where it has been one of the most common of the insects taken at electric lights. In 1897, when Mr. E. S. G. Titus was running a lantern trap for this department, he took this moth in large numbers. The record runs as follows: May 20th, 439 moths; May 22d, 2 moths; May 23d, 191 moths; May 25th, 7 moths; May 29th, 24 moths; May 31st, 31 moths; June 11th, 5 moths; June 16th, 6 moths; June 18th, 57 moths; June 20th, 76 moths; June 25th, 58 moths; Oct. 1st, 1 moth.

From my notes upon captures of this insect in 1897 I quote the following:

May 13, *Loxostege* moths have been very abundant for more than a week flying to the flowers of plum and other fruit trees.

The moths taken May 20 by Mr. Titus are about half males and half females. Dissections of the females show that the eggs are still immature in the great majority of cases.

June 8, The moths are becoming scarce. Some of those taken are full of eggs, while others have nearly finished laying.

June 10, Very few of the moths are coming to light now.

* See article by C. V. Riley in Report of the Department of Agriculture for 1892, p. 172, also article by Riley and Howard in "Insect Life" Vol. V. p. 320; an article in the same publication by L. O. Howard, Vol. VI. p 369, and an article by Lawrence Bruner in Bulletin 30, U. S. Dep. of Agr., Div. of Entomology.

From my notes of 1896 I extract the following:

May 22. Took about 500 *Loxostege sticticalis* moths last night. Cloudy and warm.

May 24. Took about 200 moths of *L. sticticalis* last night. Examined 100 moths and found that 29 were males and 71 females. The females predominating so greatly indicates that the eggs have quite largely been deposited. Dissections show that the majority of those taken have their ovaries full of eggs; in some cases the eggs are still immature, and in others many or nearly all of the eggs have been deposited.

June 10. The moths are still numerous at light and females are still found containing immature eggs.

These records with others at this station indicate maxima of the broods about the 20th of May, June, July, and August. The records have not been continuous throughout a season, but are sufficient to strongly indicate a brood of moths and worms prior to the brood that attacks the beets in July though no one seems to have discovered the worms of this brood as yet.

HISTORY OF THE WORMS IN COLORADO.

The first complaint of injuries of any importance done by this insect in Colorado that came to my notice was on the 9th of July, 1903, when Mr. H. V. Norton, living a couple of miles northeast of Fort Collins, sent word that some kind of a worm had suddenly appeared in great numbers in one of his fields and was rapidly destroying his onions and cabbages. I visited Mr. Norton's place at once and found near the center of the infested lot a small patch, perhaps a half acre, of dry uncultivated ground above water, that was densely grown up to pigweed (*Chenopodium album*). The weeds appeared to have died and dried up, but upon examination I found that the leaves had been eaten away by the worms of the insect under consideration, and that some of the worms were still upon the plants, but the great proportion of them had migrated out in all directions into the patches of onions and cabbages which were close at hand. The worms were nearly full grown and after a few days disappeared.

Two days later, July 11, I was informed that a little striped worm had appeared in many of the beet fields northeast of Ft. Collins and was doing serious injury to the plants which were still rather small. In company with Mr. Charles Evans, manager of the Ft. Collins Beet Growers Association, I visited several farms where injuries were reported. In most cases the injury was not severe. Where the worms were most numerous, in nearly every case, the field was in alfalfa the previous summer, and considerable alfalfa had been allowed to grow among the beets up to about the time of our visit. Whether the alfalfa had any direct bearing upon the presence of the worms or not is, however, quite uncertain. The late brood of worms which did the chief harm the past season, were not heard from in 1903.

During the last week of June of the past year (1904) word came from Mr. P. K. Blinn, field agent of the Experiment Station, and Mr. W. K. Winterhalter, agriculturist of the American Beet Sugar Co. at Rocky Ford, stating that a worm was troubling the beets in the Arkansas Valley. Mr. S. A. Johnson of this department was sent to investigate the matter. Mr. Johnson did not find the injuries very severe except in small areas in a few fields, and several patches had already been sprayed with Paris green or arsenite of lime in water Mr. Johnson concluded that the Paris green sprays had given best results, and especially where a second application had been made a few days after the first. A sample of the spraying outfits used, from a photo taken by Mr. Blinn, is shown at Plate II, Fig. 1. Plate II, Fig. 2, shows the work of the worms in one of the fields visited by Mr. Johnson at that time. The writer visited the same locality again Aug. 19th and was much assisted in his investigations by Mr. Winterhalter and Mr. Blinn. At this time the August brood of worms had about completed their work of destruction which exceeded that of the July brood.

The first complaint that came to the experiment station last summer was Aug. 13. On that date I went with Mr. C. M. Liggett to his ranch about 10 miles northeast of Ft. Collins and found the worms doing considerable damage. Occasional moths were still in the field. Mr. Fred Wright, agriculturist for the Ft. Collins factory, told me that the moths were abundant in Mr. Liggett's field ten days before. A week later many other fields were seriously attacked. The worms continued to increase and devastate other fields for fully two weeks, but they had nearly disappeared in Mr. Liggett's field on Aug. 22.

Mr. Timothy, agriculturist for the Greeley sugar factory, told me that he first noticed the worms at Sterling August 3, and at Greeley August 10. The worst of the injuries were over at Greeley August 20. Mr. Johnson was at Sterling August 18 and noted that the injuries were practically over there at that date. He also reported immense flocks of sparrows feeding upon the worms.

FOOD PLANTS.

I have noticed the worms feeding freely upon beets, cabbages, onions, pigweed (*Chenopodium album*), Russian thistle and alfalfa. They will probably feed upon many other plants in case of an emergency.

LOSSES.

Growers have estimated their losses all the way from one to five tons per acre as the result of the injuries by the worms.

Analyses by the chemists at the sugar factory indicate a loss of about 2 per cent. in both sugar content and in purity in beets that were defoliated badly during August. Probably more than 1000 acres of beets suffered substantial loss from the web-worm in Colorado last year.

LIFE AND HABITS OF THE INSECT.

The worms that were in the beet fields last August disappeared by burrowing into the ground to the depth of an inch or two and spinning about themselves white silken tubes from three-fourths of an inch to one and one-half inches in length, and three-sixteenths of an inch in diameter. A few of these worms changed to pupæ and emerged again as moths during September, but nearly all of them have spent the winter as worms in the silken tubes. Mr. G. P. Weldon, a special student in entomology, dug 69 of these tubes from one square foot of ground in a badly infested beet field on Aug. 31. On the same day he opened 111 tubes and found 13 pupæ and 97 worms. He also noted that the moths were quite numerous in the field, more so than a number of days previous. Moths which the writer placed over beets in cages Aug. 25 deposited eggs which began hatching Aug. 31. On September 20, I visited beet fields in the vicinity of Wellington (12 miles northeast of Fort Collins) in company with Mr. Fred Wright, Agriculturist of the Fort Collins Sugar Factory. The worms had disappeared but, although the day was cold, several of the moths were taken and many of the secondary parasites (*M. agilis*) over the beets, but there was no September brood of worms seen or heard from. Mr. Johnson took a few moths as late as Oct. 12.

Judging from the investigations by Riley and Howard, and Bruner in Nebraska and our own records at Ft. Collins, it is probable that the spring brood of moths will begin hatching about the 10th of May in the beet growing districts of the northern portion of the State, and probably about the first day of May in the Arkansas valley. We have found the moths very numerous at Fort Collins from the 10th to the 25th of May, and it is probable that they are depositing the first brood of eggs at about this time and somewhat earlier in the warmer sections as at Rocky Ford and Sugar City. At this time the beets are not up or are too small to attract the moths so that probably pigweed (*Chenopodium*) alfalfa and other plants that are more advanced serve as food for the early brood. About Sterling, Mr. Johnson noticed that the beets planted after the 25th of June escaped injury from the worms.

The second brood of moths, judging from our records, are most numerous at Ft. Collins, about the last week in June which should give a brood of worms about the 10th of July and this is the brood that did some injury to beets, onions and cabbages near

Ft. Collins in 1903 and about Rocky Ford and Sugar City during the first week of July, 1904. But it was the next, or third (?), brood that did most mischief in Colorado the past year. In the Northern portion of the State the worms were most destructive from the 10th to the 25th of August.

Most moths are on the wing only after dark, or in the twilight, but the moth that lays eggs to produce the beet web-worms is active in the day-time also and may be seen flying about the beets a week or ten days, at least, before the worms appear.

THE EGGS.

The eggs are sometimes deposited singly but usually in clusters or rows of from 2 or 3 to 8 or 10 together. They are oval in form, and about 1 millimeter long by .7 of a millimeter broad (one-twenty-fifth by one-thirty-sixth of an inch), and are quite flat below but strongly convex above. When clustered, the eggs are laid in a row, one overlapping upon another and making an angle of about 45 degrees with the surface of the leaf. In color they are a very pale green with a beautiful pearly reflection. They are deposited upon either the upper or lower surface of the leaves. In our breeding cages the greater number were deposited on the under surface. After once seeing them they are quite readily detected by the naked eye. They are shown once and a half natural size at *a* and *c*, Fig. 2, Plate I. At the end of about the second day there appears a small black speck upon the eggs as shown at *c*. This is the black head of the little worm that is developing within the shell. In about two or three days more the little worm eats a ragged exit hole in one end of the shell and escapes.

THE WORM.

The little worms are almost black at first and so small (one-sixteenth of an inch long) that they are easily overlooked. For the first two or three days the worms eat very little and skeletonize the leaves instead of eating entirely through them, but when they are about half grown and the white stripes begin to show plainly, they begin to eat and grow very rapidly so that the owner of the beets is often made to believe that the worms have migrated in the night from an adjoining crop or field. I have seen no general migrations of the worms except in a few instances where their food supply had given out or become very scanty. A peculiarity of the attacks of this insect in nearly every case that I have observed is that the chief injuries are well in the fields and almost never at the borders. We have also noticed the injuries to be worse in the higher and dryer portions of the fields but we have not found the injuries more common on light than on heavy soil. On individual plants, the young tender leaves at the center were always the last to be eaten.

REMEDIES.

If the worms are numerous enough to attract any attention at all late in the summer or in the fall, the beet ground should be plowed deeply and as soon as possible after the beets are gathered, for the purpose of burying the worms so that the moths will not be able to escape the following spring. If it is impossible to plow in the fall, then the surface of the ground should be thoroughly harrowed or disced for the purpose of crushing the worms and and bringing the tubes to the surface where freezing and thawing and the attacks of birds may destroy a large proportion of the worms.

On Feb. 28, 1905, Mr. S. A. Johnson visited a beet field near Ft. Collins that was plowed last fall and collected 94 of the silken tubes on the surface and 76 beneath the surface. The 94 tubes from the surface contained 4 living and 4 dead worms and there were 86 tubes that were empty. The last all had openings in them, some at the end but most of them had been torn open along the side, probably by birds. Riley and Howard in "Insect Life," Vol. 5, P. 321, report Mr. Walter Maxwell, of Schuyler, Nebraska as stating that cocoons that were exposed by repeated harrowings were largely emptied by birds and he mentions particularly meadow larks and quails.

The 76 tubes that Mr. Johnson dug from beneath the surface contained 52 living worms, 13 dead worms and 11 were empty. If we suppose that moths or parasites were hatched from the 11 empty tubes last fall, we should have an indication that about 20 per cent of the worms were killed from mechanical injuries from fall plowing, and a considerable additional number were killed as the result of exposure upon the surface. Those that were deeply covered, it is believed will never find their way out.

If plowing was neglected in the fall, the next best thing will will be to plow as soon as possible after the frost is out of the ground in the spring. After plowing the ground should be thoroughly pulverized and leveled so as to fill in with fine dirt between the clods and prevent the escape of the moths.

It is doubtful if anything farther can be done for this insect before the worms appear upon the beets except to keep the beet fields and surrounding territory as clean as possible of weeds that are attractive to the moths for the deposition of their eggs.

POISONING THE WORMS.

The worms accomplish their work of destruction so quickly that it is important that the beet grower should be prepared to check the injuries as soon as they are seen. In order to do this it will be necessary to be on the look out for the moths which will always appear in the beet fields from one to two weeks before the

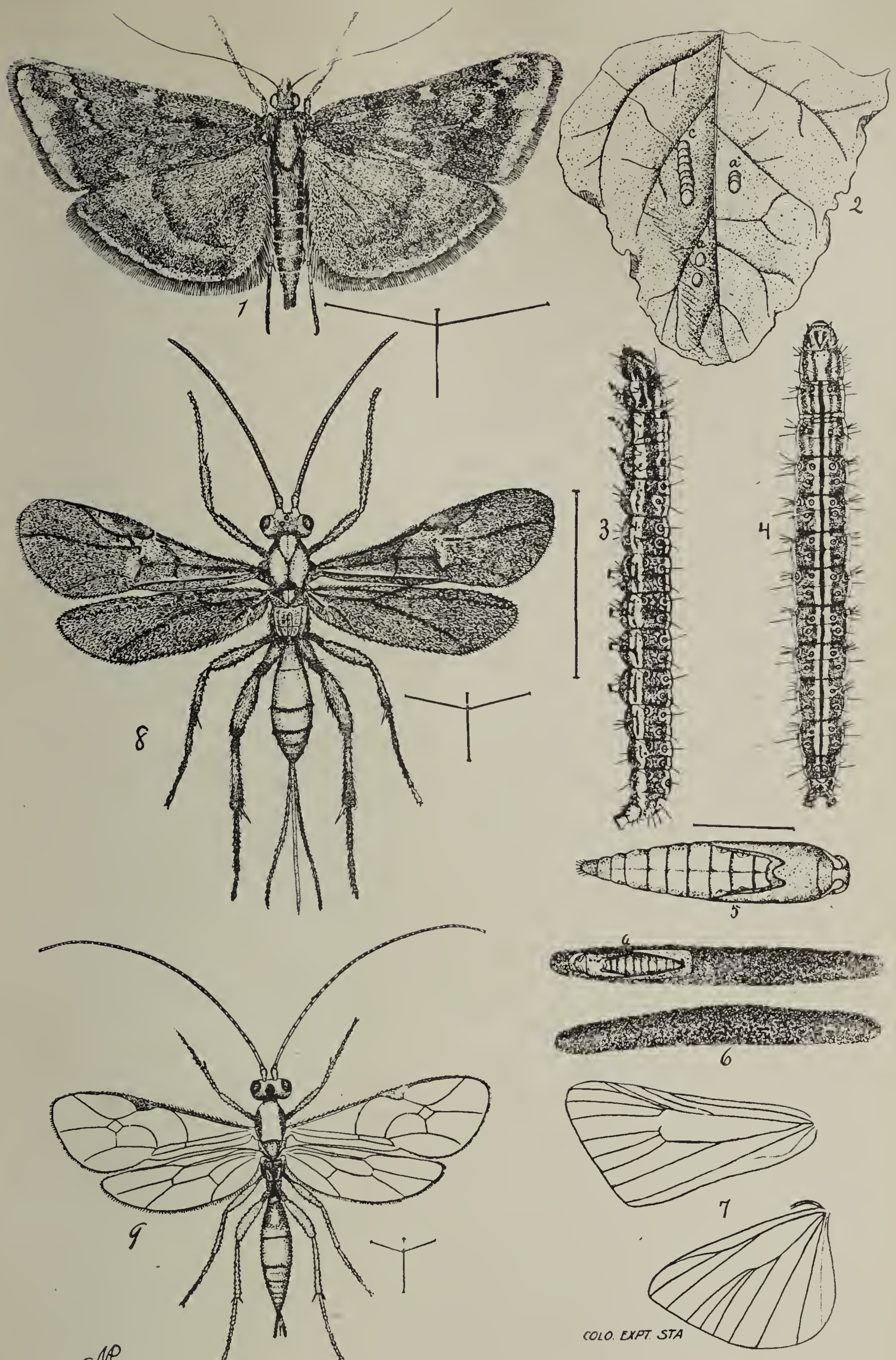

PLATE I.

THE BEET WEB-WORM AND PARASITES.

1. Moth of *Loxostege sticticalis*. 2. Eggs on leaf of beet. 3 and 4. Lateral and dorsal views of larvæ. 5. Pupa. 6. Larvæ tubes from earth. 7. Venation of wings of moth. 8. Parasite *Cremops vulgaris*. 9. Parasite *Mesochrus agilis Cress.*

Drawings by Miss Miriam A. Palmer.

COLO. EXPT. STA.

PLATE II.

Fig. 1.—Home-made apparatus for spraying four rows of beets at one time.
Fig. 2.—Beets eaten down by the beet web-worm at Rockyford, Colo., July 4, 1904.

worms will be noticed. These moths span about one inch from tip to tip of their wings when spread and are of a dark grayish or grayish-brown color. (See Plate I Fig. 1.)

They will fly up and go a short distance and then suddenly alight, usually upon a leaf of a plant. The presence of the moths in anything like large numbers among the beets should be the signal to prepare for war by procuring a quantity of poison and a spray pump or some other instrument for the distribution of the poison upon the beet leaves.

THE POISON TO USE.

Some combination of arsenic, as arsenite of lime, arsenate of lead, Paris green, or London purple should be used. The arsenite of lime is the cheapest of these but is a little more troublesome to prepare and apply. Arsenate of lead is more easily mixed and applied but is by far the most expensive poison to use. Paris green settles badly in the barrel or tank and must be kept thoroughly stirred. It would be cheaper than the arsenate of lead but dearer than the arsenite of lime. The chief objection to Paris green last year in Colorado was its serious adulteration with white arsenic causing it to burn foliage. Samples of this poison obtained at Greeley last year, where it was selling for 14 and 15 cents a pound, were badly adulterated which accounts for the low price at which it was sold. A sample of this Paris green was taken to the station chemist, Dr. W. P. Headden, for analysis to determine percentage of arsenic. The report of the analysis was as follows:

"Total Arsenic - - -	60.69 per cent.
Soluble (free) Arsenic - -	8.51 per cent."

Such Paris green is unfit to use because of its tendency to burn foliage, and it will mix with difficulty with water.

These poisons may be applied dry by means of dust sprayers, or by shaking them through porous cloth sacks (as cheesecloth) carried in the hands, or they may be applied in water by means of force pump and spraying nozzles attached to a barrel or tank. Both of these methods have their strong advocates but after considerable investigation I am convinced thoroughly that the wet spray is much better where it can be used. The principle objection to it is the expense of getting pumps and barrels or tanks necessary to spray large fields. At Plate II, Fig. 1, is illustrated a barrel sprayer mounted on cast off cultivator wheels such as is used by the American Beet Sugar company and by Mr. P. K. Blinn of the Colorado Experiment Station at Rocky Ford. One man with this barrel pump will spray four rows of beets as fast as a horse will walk across the field. The dust sprayers are very inexpensive but all that I have seen used distribute the poison very unevenly over the plants. The dust sprayers have been used quite

extensively about Greeley and many who used them seem well pleased with the results obtained.

PREPARATION OF THE POISONS.

IN WATER.

Paris green or London purple.—Mix one pound of the poison in 50 gallons of water and make a thorough and even application.

Arsenate of lead.—Mix 5 or 6 pounds of the poison in 100 gallons of water and apply thoroughly.

Arsenite of lime.—Boil together white arsenic, lime and water for a full half hour in the following proportions:

White arsenic	1 pound
Lump lime	2 pounds
Water	3 gallons

Then dilute to 100 gallons with water and apply.

Or prepare as follows: Dissolve one pound of white arsenic and 4 pounds of sal-soda by boiling them together for 15 minutes in a gallon of water. Use two quarts of this stock solution to 50 gallons of water and before using stir into it 8 pounds of freshly slaked lime of best quality. Spray thoroughly as with the other poisons.

DRY APPLICATIONS.

About Greeley the past summer the growers used the Paris green dry without any dilution and they applied from 1½ to 3 pounds to the acre. Mr. Timothy, agricultural superintendent of the Greeley Sugar Company, said they had found the dry applications very satisfactory.

Whatever the application, it must be made promptly upon the first appearance of the worms, the poison must be evenly distributed, and the treatment must be thorough, to secure good results.

NATURAL ENEMIES.

Insect-eating birds devour the worms in large quantities. Where the worms were abundant last August the blackbirds were attracted in flocks of thousands and in several instances that came under our observation the worms were all cleaned out of fields by them in the course of two or three days.

Another check which nature has provided to keep this insect from becoming too numerous is a parasitic fly with dusky wings shown in Plate I, Fig. 8, and known to science as *Cremops vulgaris.*§ The large numbers of the worms last year was probably due more to the small numbers of this parasite than to anything

§ Determined for me by Mr. E. S. G. Titus.

else, and if the worms are to be kept down without our efforts, it will probably be chiefly through the attacks upon them by this parasite. Judging from the number of parasites raised in our breeding cages last fall, it would seem that not more than 10 per cent of the worms were destroyed by them last summer. The reason for the small numbers of this friendly parasite we can blame partly, if not entirely, to the presence of another yellow, clear-winged parasitic fly (*Mesochrus agilis* § *Cress.*) shown at Fig. 9, of Plate I, which preys upon the smoky winged parasite of the worms, and so is an enemy of the beet grower. In capturing these parasites over the beets last fall we took almost as many of the clear winged parasite as of the other. This, together with the fact that the worms have passed the winter in good condition makes it seem probable that the worms may appear in large numbers again the coming season but of this we cannot be certain. I would, at least, advise all beet growers in Colorado to be prepared to treat their beets on short notice with some arsenical poison in case the worms should appear.

SUMMARY.

The worms have passed the winter in good condition and the moths will doubtless appear in large numbers about the middle of May.

The May brood of moths will probably lay their eggs upon weeds and other plants and not trouble beets.

If the worms from the May brood of moths succeed in developing well, another large brood of moths may be expected about June 20, from which may be expected the first brood of worms upon the beets, about the first week in July.

Should the July brood of worms meet with no disaster, look for a second brood of worms upon the beets about the middle of August. This brood will probably be more extended than the the others and may appear to consist of two or three broods close together.

The exact time of the appearance of the broods will vary in different portions of the state and with the earliness or lateness of the spring.

Be prepared with poison and spray pump so as to strike the blow in time to prevent serious injury to your beets if the worms should appear.

Where worms have appeared during late summer or fall, always plow the ground deeply before winter if possible and harrow the surface. Failing to do this, plow as soon as possible in the spring and work the surface as finely as possible with disk and harrow.

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§ Determined for me by Dr. L. O. Howard.

Adverse weather conditions or abundance of their enemies may prevent the occurrence, in destructive numbers, of any of the insects mentioned in this bulletin this year, but be on the look out for them.

Whenever insects are troubling your crops, write the Experiment Station for information and send specimens.

THE BEET ARMY-WORM.†

(*Caradrina exigua Hub.*)

This insect might easily be taken for the Beet Web-worm. The moth is a little larger than that species, spanning a trifle more than an inch from tip to tip of wings when spread. The fore wings are quite uniformly grayish brown in color with a pale spot about mid-way near the front margin, and the hind wings are almost pure white except for a narrow strip on the anterior margin which is darker. See Plate III Fig. 1. The worms are also a little larger when fully grown being about an inch and a quarter long. They are also plumper in form, greenish in color and without distinct white stripes, but often with quite distinct dark lateral stripes. See Plate III, Fig. 2.

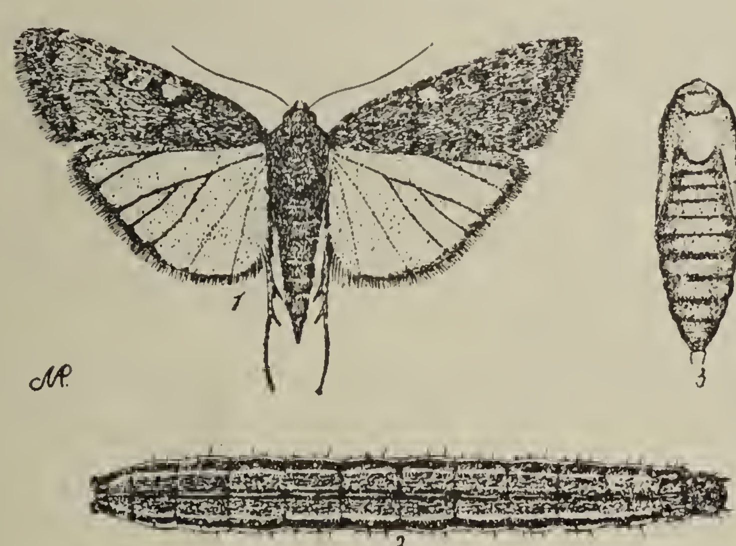

PLATE III.
THE BEET ARMY WORM (*Caradina exigua*).
1. Adult moth. 2. The Army Worm, dorsal view. 3. Pupa.

The pupa, or chrysalis, is a good half inch long, mahogany brown in color and has two straight slender spines at the small end as shown in Plate III, Fig. 3.

So while these two insects are much alike in general appearance and in the damage they do, they are easily separated in any stage of their development. Their habits are also quite different as we shall see presently.

† This insect was treated in Press Bulletins 1 and 3; Report 12, p. 39; Report 13, p. 128; and Bull., 64; pp. 4 and 10, of this Station.

About the 10th of August, 1899, the worms of this insect seemed suddenly to appear in fields of sugar beets about Grand Junction. Many acres of beets had their tops all eaten away and then the worms turned their attention to the beets themselves eating them out below the crown. Mr. H. H. Griffin, then at Rocky Ford, reported this insect as doing some injury to experimental plats of sugar beets in that locality. Since 1900 this worm has been reported as doing some injury to beets in the Arkansas valley, but it has not been reported in injurious numbers since 1899 at Grand Junction.

LIFE HABITS OF THE INSECT.

The worms that were so numerous in the Grand Valley in 1899, burrowed into the ground to the depth of about an inch when they became full fed, formed an earthen cell about themselves, apparently without spinning any cocoon, and from these cells the moths appeared in great numbers during the latter part of August and September. The moths appeared so late that it seems probable that they hibernate during the winter in that stage, but of this I have no positive knowledge. I was shown injuries done to beets by this worm during June of the same season at Grand Junction, so there are two, and possibly three broods of this insect in a year.

In June 1900 Mr. E. D. Ball visited Rocky Ford where this insect was doing some injury and learned that the worms began hatching about June 1st, and that the moths were noticed in the fields two weeks prior to that date. He also noted that early planted beets suffered most and the application of Paris green had proven a satisfactory remedy*.

The following life history notes are extracted from breeding cage records kept by Mr. Ball upon the development of worms of all sizes taken by him at Las Animas, July 16, 1901, while an assistant in this department:

July 22, 1 chrysalis, (or pupa.)
July 24, another worm in earthen cell ready to pupate.
July 27, several worms have pupated in the last few days.
July 29, all have changed to pupæ.
Aug. 5, first moth emerged.
Aug. 6, another moth.
Aug. 7, another moth and a parasite from July 22, pupa.
Aug. 8 to 14, one to 4 moths each day.
Aug. 9, four moths that hatched today were put in a cage with sweetened water which they ate freely.
Aug. 14, 552 eggs have been laid upon under side of leaves and upon sides of cage. They are in groups of from 12 to 50 and each group is coated with a white downy secretion.
Aug. 15, some of the eggs are looking darker.

*See 13th Annual Report of Colo. Agrl. Exp. Sta. p 128.

Aug. 16, half of the eggs are hatched and worms are feeding on leaves. Last night 38 more eggs were laid.

Aug. 17, nearly all of the 552 eggs are hatched.

Aug. 18, 14 more eggs laid last night.

Aug. 21, the eggs laid Aug. 16 have hatched.

Aug. 22, the eggs laid Aug. 18 have mostly hatched.

Aug. 22, 1 male moth dies.

Aug. 24, 100 fresh eggs laid.

Aug. 25, 1 female moth dies.

Aug. 29, another female moth dies. Total eggs laid by the two females, 704. Time from emergence to laying first eggs, 5 days; to laying last egg, 16 days. Time required for eggs to hatch, 4 to 5 days.

The writer was at Palisade, Colo., July 8, 1901, at which time the worms were found in all stages of growth upon beets. The small worms were usually found in groups of from 3 or 4 to 6 or 8 beneath slight webs which they spin for protection. These worms were most common upon the younger central leaves and were more common below than upon the upper surface. The webbing continues with this insect until the worms are nearly grown. In the early stages of the worms they skeletonize the leaves as in the case of the web-worms. Worms taken July 8th at Palisade began changing to pupæ July 14th.

REMEDIES.

When the beets have been gathered it is too late to destroy this insect by cultivation, but a thorough stirring of the surface soil immediately after the worms disappear would probably destroy many of the pupæ in the ground.

The worms may be destroyed by the use of poisons the same as in case of the preceeding species.

CUTWORMS.

BY S. ARTHUR JOHNSON.

Each year farmers and gardeners suffer greater or less loss from the ravages of cutworms. This loss is commonly most severe in the spring or early summer when the crops are just appearing. Injuries occur in midsummer, as well, but they are commonly unnoticed because of the abundance of vegetation. By proper care these may be largely if not entirely prevented. Cutworms are quite generally distributed and in favorable seasons become so numerous that farmers are dismayed at the prospects of losing a crop.

LIFE HISTORY AND HABITS.

Injuries.—The most common and injurious species in this state is peculiar to the Rocky Mountain region, and is figured in the accompanying drawing. In times of great abundance it will travel in immense numbers in search of food, in consequence of which it has been called the "Army Cutworm." An outbreak of this kind cccurred in Colorado in the spring of 1903 and is quite fully reported by Prof. Gillette in Bulletin 94 of this Station. During the previous season the moths were unusually abundant. They always fly at night and hide by day among the leaves of trees, in the grass, under boards, or other places of shelter. In the suburbs of Denver they fairly beseiged the houses when the lamps were lighted. In a very few minutes after dusk the windows and screen doors would be covered with moths. They crept in by every crack and crevice much to the annoyance of the people who were at times forced to put out the lights and retire to escape the enemy. The insects were noticeably more abundant at houses near alfalfa fields.

Dates of Appearance.—The college records show that this and the closely allied species, *Chorizagrotis agrestis* and *C. introjerens*, appear in two broods, the dates of the spring captures at Fort Collins ranging from April 16th to July 27th, and those in the fall from September 3d to October 12th. These dates, how-

ever, represent only stragglers at either ends of the broods. The greatest abundance of the moths in the spring comes between the middle of May and the first of July and in the fall in the later half of September.

Eggs.—The eggs laid by the fall brood cause the troublesome worms in the spring. The eggs are laid almost exclusively upon vegetation, and, although the worms are very general feeders, they appear to show some preference for particular crops. They are always more or less abundant in fields of alfalfa. Where virgin soil is broken they may usually be found. A significant instance came to our notice two years ago. In a number of cases cutworms were quite destructive to sugar beets where these were planted in ground which bore a crop of barley the previous year.

When the egg is laid it is white in color, hemispherical in shape and attached to the leaves or grass by the flat side. Under the magnifying glass it shows beautiful striations which radiate from the center toward the edge of the disc. Before hatching, which occurs in a very few days, the eggs become brown in color.

Young Worms.—The young worms are very small and travel about for a short time with the looping motion of the measuring worms. They feed during the night and hide by day under some protecting object or in holes which they make in the ground.

Hibernation.—By the time cold weather begins the young are about half grown and range from a half inch to an inch in length. In color they are brownish or greyish with in many cases a distinct greenish tinge. At this time they are provided with three pairs of sharp pointed feet under the forepart of the body and four pairs of blunt proplegs under the posterior part. In this condition the worms spend the winter buried in the ground.

Spring Injuries.—With the warm spring days the worms come to the surface at the time the first blades of grass and leaves appear. Their appetite is now ravenous. Their growth during the fall has been rather slow, but now the size increases by leaps and bounds. At this time of year vegetation is scarce. Most of the green has been killed by the winter's cold, and the young, tender shoots, which give promise of harvest, furnish a most pleasing feast for the hungry worms. Then the seriousness of the pest becomes evident, especially if the field has been recently plowed and seeded or set with plants, in this way reducing the amount of food. In beet fields the worms cut off and devour the seedlings as soon as they appear above the ground, often following along the drill mark and taking everything in the row for several feet.

Full Grown Worms.—The worms are now between one and two inches in length, rather plump and sluggish, and have a habit of curling up when touched or suddenly exposed to the sunlight. The color is dull green or greenish brown. Two broad, irregular stripes extend down the back which are lighter in color than the rest of the body and more brownish. On the sides will also appear broad light colored lines. The number of proplegs is now found to be five pairs. The easiest way to discover the presence of worms in the field is to examine under boards, clods and other objects, or dig in the earth near the base of plants. Often when a plant has been injured the culprit may be found by digging in the ground near it. They seldom bury themselves to a greater depth than two inches.

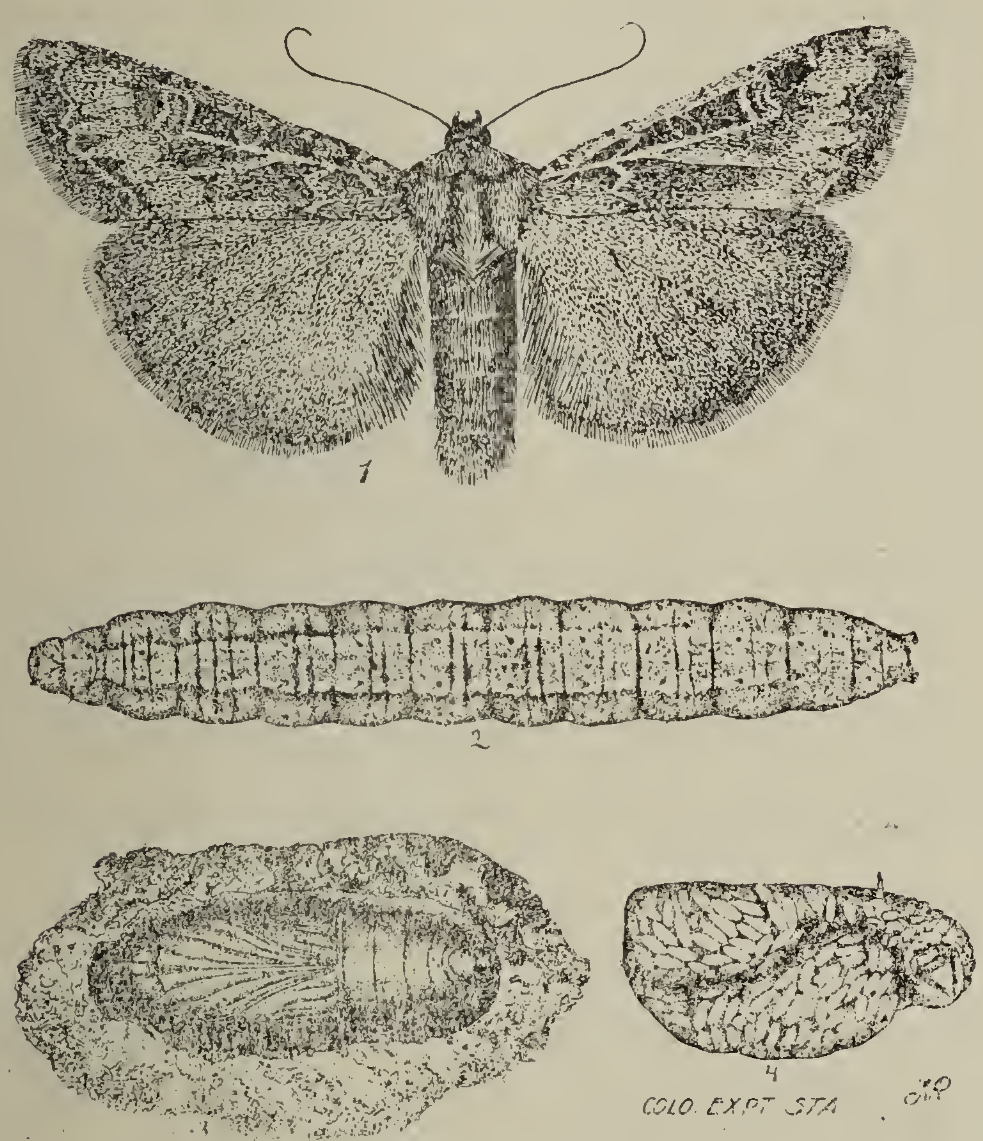

PLATE IV.

THE ARMY CUTWORM. (*Chorizagrotis auxillaris.*)

1. The adult moth. 2. Full-fed larva. 3. Pupa in case of hardened earth.
4. Cutworm filled with chrysalids of tiny parasite.
[We have reared as many as 2005 of these parasites from one cutworm.]
All twice natural size.

At Aurora, near Denver, in 1903 the larvæ were so abundant that they ate off entire fields of alfalfa. The early garden crops were almost entirely destroyed. The larvæ covered the sidewalks in such numbers that it was impossible to walk without

crushing them under the feet. They crawled in at the doors and became a household pest. Mr. Rauchfuss saved his garden by hunting the worms with a lantern at night. The field injuries were most noticeable in the cases of early sown barley, sugar beets and alfalfa of one year's standing. At Fort Morgan Prof. Gillette found that there were two distinct forms of attack. Where virgin soil had been broken, the larvæ were abundant in all parts of the field and the entire crop in some cases was taken, the young plants being eaten down to some distance below the surface of the ground. In other places where the ground was plowed the previous fall the field itself was not infested, but the worms migrated in from adjoining lands to a distance of several rods denuding the ground as they went. See Plate IV, Fig. 2.

Pupation.—When the larvæ have attained their full growth they make vertical burrows in the ground to the depth of about two inches and change to the chrysalis form with the head of the chrysalis pointed to the opening of the burrow. This change usually takes place in May or early June. Of course injuries cease when this transformation is accomplished. The chrysalis is dark brown and much shorter and more plump than the worm from which it came. See Plate IV, Fig. 3.

The Adult Moths.—The adult moths appear in about a month. They have a ground color of blackish brown. In the species whose life history we have just been over, the front wings are marked with lighter brown. The front and back edges are margined with this and patches occur between these lines. The back wings are lighter than the front and are dusky in color, darkest on the outer margins. The eggs are laid shortly after the moths appear and the summer brood of worms live and produce the fall brood of moths. See Plate IV, Fig. 1.

ENEMIES AND PARASITES.

The rate of increase in cutworms, as in most insects, is enormous, but this is offset commonly by the raids made upon them by their natural enemies. When the parasites fail to keep the insect down, things become serious for the farmer. The enemies may be divided into two classes; those which prey upon the worm, killing and eating it, and those which live within and upon the tissues of the worm, finally killing it.

Vertebrate Enemies.—To the first class belong chickens, birds, ground squirrels and pigs. Under the conditions existing in Colorado, probably the birds are the most useful. Quail, meadowlarks, bluebirds and bluejays are known to feed upon them. The flocks of blackbirds which constantly patrol the fields destroy immense numbers. When a field of alfalfa is flooded

the worms crawl out and are thus exposed, the blackbirds congregate and help to rid the farmer of his hungry foes.

Parasites.—The insects which live within the worms are many in kind and number. The maggots of several kinds of flies attack them. Wasp-like insects, both large and small, help in the good work. Two species of the larger kinds (*Ichneumon longulus* and *Amblyteles subrufus*) have been reared at the Station while the worms at Denver two years ago were very largelyparasitized by a tiny insect belonging to the genus *Copedosoma.* Plate IV, Fig. 4. Counts were made from those reared from several worms and gave in individual cases from one to two thousand. So many of the worms were overcome by these agencies that there was no recurrance of the pest.

REMEDIES.

There are two methods by which injuries may be controlled. One is preventive and aims to forestall trouble, and the other tends to lessen losses after the injuries are noticed.

Preventive.—Early fall plowing will almost surely prevent the presence of worms in the field, for it leaves no vegetation on which the eggs may be laid. In the case of alfalfa, plow to the depth of three or four inches in September. This will not only prevent the pest, but will give the young foliage time to rot and furnish nourishment for the young beets. After plowing, harrow or otherwise treat the field so that it will be kept bare until winter sets in.

Late fall plowing is almost equally beneficial for it turns the young worms under so deeply that they seldom come to the surface or else it exposes them in such a way that they fall an easy prey to the watchful birds or the inclement weather.

Clear away all rubbish from the borders of the field. Such collections furnish the best kind of shelter for the worms over winter, from which they may invade the growing crop.

If the field has not been plowed in the fall for any reason, it should be thoroughly examined for the presence of the pest in the spring. This may be done by examining under any object which may be laying on the ground. It would be well to lay bits of board or shingles in different places and look under them every few days for worms.

Alleviative.—If the worms are present in the fields in the spring, they may be almost surely checked by one of the following practices:

Spray heavily with Paris green or other arsenical mixture a growing patch of alfalfa or grass, mow it close to the ground and

spread over the plowed field in small handfuls at a distance of every few feet. The Paris green should be used at the rate of one pound to a hundred gallons of water and the grass distributed late in the day so that it will not wither before the worms attack it at night. Of course ground must be sprayed which will not soon be eaten over by stock. If desirable the poison may be mixed in a barrel of water and the green material dipped into it and then distributed over the ground. The water must be constantly stirred to keep the poison in suspension.

If fresh vegetation is not available arsenic bran mash may be used. This is made by the method used for grasshoppers. The U. S. Department of Agriculture gives the following directions for preparing this insecticide: "Paris green, arsenoid, white arsenic, or in fact any arsenical can be used for poisoning this bait, and in its preparation, on account of the weight of the poison and the fact that it soon sinks to the bottom of the water when stirred, it is best to mix the bran with water and sugar and then add the poison. The proportions are two or three ounces of sugar or a similar quantity of glucose or molasses to a gallon of water and a sufficient amount of bran (about a pound per gallon) to make, when stirred, a mixture that will readily run through the fingers." About one pound of poison should be used for every fifty pounds of bran. Often syrup may be had at the sugar factories at a very much cheaper rate than the cost of the other sweetening materials. Scatter this preparation over the fields late in the day, preferably when the ground is bare, either before the seed is planted or before it comes up. Dr. John B. Smith is authority for the statement that a field may be cleared in forty-eight hours by this means. If the beets have already begun to come up the bait should be placed in little heaps of a tablespoonful each along the rows.

A dry mash composed of Paris green 1 lb., equal parts of bran and middlings 20 lbs. is recommended by Dr. Forbes.

Either of the bran preparations are dangerous to fowls and these should be kept off the fields for several days.

Bulletin 99. **March, 1905.**

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

How Can We Maintain the Fertility of Our Colorado Soils?

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1905.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

HOW CAN WE MAINTAIN THE FERTILITY OF OUR COLORADO SOILS?

BY WM. P. HEADDEN.

This bulletin has no other purpose than to present to the farmers of Colorado some of the most patent facts relative to the maintenance of the productiveness of their lands. The writer has presented this subject repeatedly, either in lectures before Farmers' Institutes or bulletins, and particularly in the pages of our too short-lived *Agricola Aridus*. The presentation of this subject has, heretofore, apparently failed to attract the attention of our farmers, either because of the unskillful manner in which it has been presented, or because it was not opportune, the farmers not yet having come to a realization of the importance of the question, as one appertaining to their lands and to their prosperity. The time may be more auspicious for obtaining the attention of a reasonable percentage of the persons for whose benefit the Experiment Stations have their existence. It is in hope that this is the fact, that I present the following considerations, and not for the purpose of presenting any new results, or any facts which are not already well known.

OUR COLORADO SOILS ARE NOT INEXHAUSTIBLY RICH.

In the early days of Colorado agriculture, when the railroad land agent was endeavoring to induce homeseekers to settle on our prairie lands, it was, perhaps, pardonable to emphasize their virgin condition and to claim for them inexhaustible fertility. This fiction was soon dispelled by the plain facts, so plain that no one could misunderstand them. The magnificent yields of the first few years after the lands were brought under irrigation, were followed by rapidly decreasing ones, until they fell to one-half or one-third of their former weight or measure, and it became evident to the most obtuse that a remedy had to be found.

That this result would ensue, and that rapidly, was easily to be foreseen; the nature of our soils justified no other belief or expectation, and we now begin to apprehend that in our climate itself we have added reasons for the fact that the virgin fertility of our soils was of comparatively short duration when subjected to continuous cropping without fertilization.

Our soils on the eastern slope of the Rocky mountains are, for the most part, light, sandy loams. The heavier, clayey soils, derived largely from the disintegration of shales, especially of the Ft. Benton shales, are apt to come under the class of soils designated as gumbo, which, to use the language of an earlier writer, is inimical to vegetation. The soils derived from the strata of the Jura-Trias may be somewhat clayey, occasionally limey, due to the presence of calcite or ordinary lime stone, or to the presence of gypsum, the latter mineral being of common occurrence in portions of these strata.

ORIGIN OF OUR SOILS.

The origin of our soils may safely be ascribed to the breaking down of the rocks forming the mountains to the west of us. The mountains from which the material of the strata of the Jura-Trias were derived may not have been the present mountains, but the material composing them is so similar to that yielded by the disintegration of the Front Range, that there is no reason for discussing the possible differences in origin.

The rocks of the mountains are essentially granitic in character, and the sands and soils derived from their disintegration will naturally partake of this character, too. It is a fact that the soils from the foothills to the eastern part of the state are sandy or gravelly loams, in which the sands and gravel are composed of quartz and felspar grains, with some mica plates; in some places they may be coarser than in others, especially in river bottoms they may be finer, but we have everywhere the same general composition with but little variation, and this restricted to small sections.

The base of our soils, mineralogically, is very uniform. The fact that they are nearly all sandy loams tells us that these mineral grains still possess their mineralogical characteristics; they have been broken and ground to small sizes, but they have not been materially changed in their composition. The felspar, hornblende, augite or mica are the same rocks that form the mountain masses, only that they have been broken up into very small pieces. If we examine the red, clayey soils, corresponding to the Jura-Triassic strata, we find the same to hold true to a very great extent. The red sandstones of this formation show the same facts.

Such are the salient, mineralogical characteristics of our soils. The mineral which can furnish the potash is a felspar, orthocluse, which yields slowly to the decomposing action of water and air, and to some extent, to the action of the roots of the plants. The total amount of potash in our soils is from two and one-quarter to two and one-half per cent. of the weight of the soil. A comparatively small portion of this, however, exists at any given time in such form as to be readily taken up by plants. Before this can take place, the

felspar must be altered and the potash brought into another form, or, in other words, it must be prepared for the use of the plant. In our virgin soils, this preparation had, to a certain extent, taken place, but this supply of prepared, available potash was quickly used up, and the magnificent crops of the first few years gave place to poor and unremunerative ones.

The phosphoric acid in our soils is also furnished, certainly in a large measure, by the felspars. A sample of this mineral, just as it was broken from the granite of which it formed a part, contained more phosphoric acid than some of our soils. The amount was below the minimum considered necessary to a fertile soil, but was equal to or greater than the amount found to be present in sixteen out of fifty-five samples of soils representing the different counties of this state.

The same facts pertain to this substance, regarding the extent to which it is prepared to be taken up by the plant, or, as it is generally expressed, its availability, as to the potash.

OUR SOILS NOT RICH IN POTASH AND PHOSPHORIC ACID.

The average Colorado soils, as represented by a considerable number of samples from almost as many portions of the state, are not very rich in these elements of plant food, potash and phosphoric acid; that is, the amount of potash taken up by dilute acids is very moderate indeed, while the total amount of phosphoric acid is comparatively small, only about one-tenth of the samples analyzed showing two-tenths of one per cent. or more, and about one-third of them as much as one-tenth per cent. or more. This statement, unlike the one relative to potash, has reference to the total amount of phosphoric acid present, because dilute acids extract the whole of it from the soil.

THE NITROGEN IN OUR SOILS.

This element may be considered as having been furnished wholly by the agency of animals or plants. It is the most variable plant food in soils in general, depending, also, to a considerable degree, on conditions of climate, which are of less effect in the cases of potash and phosphoric acid. There are the same questions of availability regarding the nitrogen as regarding the other two plant foods mentioned. But assuming that a fairly productive soil contains about one-tenth per cent. of nitrogen, nearly all of our soils would measure up to this standard, but only a comparatively small number of them would have a considerable excess above this, less than one-third of the samples analyzed showing as much as two-tenths per cent. of nitrogen.

The statements made in the preceding paragraphs pertain almost exclusively to virgin soils.

These, then, were the conditions under which our agriculture began. It is a well known fact, that the farmers very soon began to feel the need of doing something to keep up the yield, particularly of the cereals, because this was the first class of crops raised.

THE COST OF GROWING CROPS.

In these early days the soil bore the burden or cost of raising the crops, and the farmer made no estimate of this; even now he seldom takes this factor into account. A ton of alfalfa, perhaps one of his cheaper crops, is charged with the rent of the land, cost of irrigating, cutting and stacking. There is seldom any question as to whether the ton of alfalfa has cost the land any of its fertility or not. The time has already arrived when these questions of cost in soil fertility must be taken into account. I have taken alfalfa because it is our popular forage plant, and very justly so. I shall use figures in this calculation which I published ten years ago, but they are the same facts, just as true as they were then. The cost of the ton of alfalfa in soil fertility will be best understood if we consider it to have been sold off of the ranch. With the ton of alfalfa hay, cut when the plants were in half bloom, there would be sold fifty-five pounds of potash, ten pounds of phosphoric acid, and fifty-two pounds of nitrogen, some of which, however, came from the atmosphere. I do not know how much of it really came from the air and how much from the soil, but I will assume that one-half of it came from each, and we will use the trade values for these substances as given for 1904. The fifty-five pounds of potash, at 5 cents per pound, is worth $2.75; the phosphoric acid, in cotton seed meal, etc., is quoted at 4 cents, and the 10 pounds in the ton of alfalfa is worth 40 cents. Considering that one-half of the nitrogen is obtained from the soil, we will have 26 pounds of nitrogen to charge against it at 17 cents per pound, or $4.42, a total cost in soil fertility, which would have cost, bought in the market in 1904, $7.57. As it may be better understood by some, I will express it as the cost of raising four tons of alfalfa hay per acre, which would be $30.28.

The sugar beet is a crop which is now grown on a large scale in several sections of the state. The crop harvested in this immediate neighborhood in 1904 was 80,000 tons. What was the money value of the phosphoric acid, potash and nitrogen removed from the soil by this crop at the current prices of these substances, *i. e.,* 4 cents per pound for phosphoric acid, 5 cents per pound for potash, and 17 cents per pound for nitrogen. These are the values adopted by some of the Eastern Experiment Stations and would be too low for our market. The 80,000 tons of beets would contain 331 tons of potash, worth $31,100; 71 tons of phosphoric acid, worth $5,680; 160 tons of nitrogen, worth $54,400; a total of

$81,180 for the crop, a trifle over one dollar per ton. In other words, had the farmers of this immediate neighborhood who sold their sugar beets to the local factory, been compelled to pay the market prices for the potash, phosphoric acid and nitrogen removed from their lands by the beet roots taken to the factory, it would have cost them $81,180.

These examples serve thoroughly well to emphasize the fact that there are other items of cost in raising a crop, even of alfalfa, than those previously mentioned, *i. e.,* land rent, labor, etc., and to show that the cost in the diminished fertility of the soil may be a very important item.

Our farmers can no longer afford to treat this subject with indifference or utter neglect, as they have done in years past, and as they do to a considerable extent even at the present time. We have shown that the soils are by no means inexhaustibly rich; even our virgin soils are not. In fact, none of them are more than moderately rich in the essential elements of plant food.

CLIMATE AND FERTILITY.

Our climate does not seem to be especially favorable to the formation of that form of organic matter known as humus, which favors the retention of nitrogen until it can be converted into a form fitted for its taking up and assimilation by the plant. The moderate supply of plant food, our climatic conditions which favor the complete destruction, the burning up of the organic matter in the soil rather than its humifaction, and every other condition which tends to lessen the fertility of our soils, admonishes us to vigilance in the preservation and enhancement by every means within our power of the intrinsic value of our lands, which is their power to produce.

This view is supported by the experience of ranchmen or farmers throughout Colorado, and while it is in perfect agreement with the theoretical views held regarding the fertility of the soil and its durability, it is simply a plain matter of fact not fully appreciated as yet, but one which is coming to be more and more generally acknowledged, even by the most careless and indifferent.

The necessity of carefully considering this question cannot be too strongly urged upon all classes of our agricultural population. This will undoubtedly seem a self-evident fact, even a trite one, to many persons, but a very little observation of the practices of our farmers will convince any one that it cannot be repeated too often.

CAN WE PROFITABLY REPLACE THE PLANT FOOD REMOVED?

There is a very important question confronting us, *i. e.,* can we, by any available means, restore the plant food removed by our crops, sugar beets, for instance, at such a cost as will permit us to make a

reasonable profit? The question of our being able to maintain the fertility of our lands is one thing, but the question of its cost is another. It is clear that the returns, either in the present or in the immediate future, must not only pay the cost of maintenance of the fertility, but must permit of a profit. It must, in other words, be accomplished in some business way which must be approved by an increased prosperity.

The means at our disposal with which we may endeavor to meet this question are such as other communities possess, but the questions of costs and local conditions, and perhaps methods or practices dependent upon the latter, may prevent us from availing ourselves of some means which, in other places, have been very efficient. I wish that I could emphasize the fact that the Colorado farmer, while he may avail himself of the observation and experience of others, must solve his own agricultural questions, the maintaining of the fertility of his soil and the earning of profits for himself.

Colorado is not a sea-board state and its agriculture cannot look to the products of the sea as a means of restoring the waste of its lands. Among its varied mineral resources there has not as yet been found phosphorite, apatite, or other rock phosphate, or any salt of potash in such quantity as to permit of its use in agriculture; its packing house industry is too small to supply any quantity of waste or by-products nearly adequate to supply the elements of fertility which we are annually using up. Our manufacturing interests are producing no by-products, such as phosphatic slags, to which we can have recourse. In regard to our sources of nitrogenous fertilizers, we are no better off. Our coke industry might be made to yield us some in the form of ammonia salts, our packing industry a little in the form of dried blood and other forms, but these are all insufficient to supply an amount nearly equal to our actual consumption.

CAN WE USE POTASH SALTS?

If we use German or Stassfurt salts as a supply of potash, we must realize from its use a sufficient return to pay for its production, preparation, marketing and delivery to us, together with the profits put on by the producer and dealer, and leave a margin of profit for the farmer who uses it.

Can the Colorado farmer profitably use these? The answer depends upon two things: First, upon the price that he must pay for the potash. This, of course, depends upon the actual cost of the salt, including transportation, and the modesty of the profits realized by all of the interested parties. Second, upon the increased productivity of the soil, considering the total increase in both quantity

and quality of crop, whether it is produced during the season of its application or later.

The writer does not know of any series of experiments showing conclusively that the Colorado farmer can make a profit by using this salt on general crops, and will certainly be pardoned, if he does not find some sympathy, in entertaining a serious doubt regarding the feasibility of our using this salt for maintaining the supply of potash in our Colorado soils.

CAN WE USE SUPERPHOSPHATES AND CHILI-SALTPETRE?

The preceding considerations apply to the questions relative to phosphoric acid, whether it comes from Canadian apatite, or phosphatic rock from Tennessee, South Carolina or Florida. They also apply to nitrogen, whether it is in sodic nitrate from Chili, or in dried blood, meat, etc., from the packing houses of Chicago. I have assumed throughout that the trade would by every means, consistent with a reasonable business proceedure, for it is always entitled to a legitimate profit which no one ought to begrudge, endeavor to make the use of such fertilizing materials profitable in order to extend their business.

It, however, seems to me to be a serious question whether we can, with any hope of realizing a profit, look to these means of maintaining or restoring the fertility of our soils, except perhaps in a few special cases as, perhaps, in market gardening in the vicinity of our larger cities.

BETTER PRACTICE REGARDING BARNYARD MANURE.

In the past, even up to within a very few years, not more than three or four years ago, but little or any use was made of the manure accumulating about our towns and the corrals where hundreds of animals had been fed. Within the past year it has been possible for us to find piles of manure five, ten and even twenty years old, which have lain there just as they were piled when the corrals were cleaned out.

At the present time this is one of the most important and, at the same time, available means for the maintenance of the productiveness of our fields, *i. e.*, the careful husbanding of all the products of the farm which can economically be converted into a fertilizer—say into barnyard manure.

Our former practice was, in cases where the alfalfa was fed upon the ranch where it was grown, to neglect the refuse or perhaps haul it out to dump it in some boggy place; if it were sold off of the farm no further account was taken of it—another crop would grow. So little appreciation of this subject, which is of the very greatest importance to the agriculture of this section, has heretofore been evinced, that it has been possible, within the three years last

past, to obtain at the corral a four-horse wagon load of well-rotted manure for a consideration of twenty-five cents. This time is past, it lasted altogether too long.

WHY SAVE THE BARNYARD MANURE?

I intentionally chose alfalfa as an illustration to show that it cost a great deal to raise a crop, which I endeavored to make evident by converting the elements of fertility into their respective money values, which for a four-ton crop of alfalfa, per acre, amounts to $30.28, assuming that only one-half of the nitrogen present in this amount of alfalfa hay was obtained from the soil. I realize that it is difficult for the average ranchman to appreciate this fact, for it represents money value which he has never had represented in his bank account, nor has he ever seen the materials in mass, nor can he miss them from the place whence they have been taken. They are, nevertheless, no longer there, but have been embodied in the hay and removed with it. There is less plant food by this much in the soil than there was before.

It costs less, not in the labor of plowing and preparing the seed bed, or of irrigating and harvesting, but in soil fertility, to grow a ton of wheat, or oats, or rye straw, still it cannot be grown except at a cost, and after it has grown and produced its crop of grain, it still has a value which is of too much importance to be permitted to, in any degree, go to waste. Thousands of tons of this material are left in the fields where stock has access to eat what it may, but very large quantities of it are removed before the next plowing by the ready means of the match, whereby the nitrogen and the organic matter, both beneficial to our soils, are dissipated in the atmosphere, while the ash constituents would have been far more valuable if applied jointly with the other constituents of the straw. The glow of the burning straw pile is, even in this year of 1905, not an unusual sight. This, too, has been a wanton waste of fertilizing values which the future will teach us to utilize in a rational way.

Cattle feeding in the vicinity of Fort Collins has given place to lamb feeding, at least, to a large extent. The number of lambs which have been or are being fed in this immediate neighborhood during this season, the winter of 1904-1905, is about 250,000 head. In order to get a clear idea of the important bearing of the question of barnyard manure upon our agriculture, I will estimate the manurial value of the voidings of 250,000 sheep, using conventional but conservative data.

First, we will assume the feeding period to be 100 days; second, we will take the daily consumption of alfalfa at three pounds; third, we will assume the manurial value of alfalfa hay to be $11.90 per ton; fourth, that the voidings of the sheep contain 95 per cent. of the manurial values of the hay; fifth, that no corn has been fed.

On these assumptions, the total weight of hay consumed will be 37,000 tons, with a manurial value of $431,300. The voidings equal 95 per cent. of this value or $409,735. I do not mean to say that this full value can be realized or that no losses will occur, but it is a fact that if our community should desire to purchase the amounts of potash, phosphoric acid and nitrogen contained in the voidings of these 250,000 lambs for 100 days, each lamb consuming three pounds of alfalfa per day, it would cost them not less than $409,735.

Is it feasible to preserve the whole of the voidings? Very nearly all, and the straw, which is still burned in considerable quantities, could be used to good advantage as an absorbent and would thereby be converted into an excellent form for application as a manure. We know that no one man in the community would reap the benefit of this great value, but the community as a whole should. While I have singled out the sheep feeding as an example, the principle applies to every individual, whether he keeps only one horse or a cow, or is a feeder on a large scale. Everyone ought not only to try to preserve and utilize all of the barnyard manure naturally produced on his farm, but he ought to use every practicable means to increase the amount. While this is particularly applicable to the farming districts, it applies in a less degree to the towns and cities as well.

In using barnyard manure which is produced upon the farm, we preserve, in a large measure, the plant food originally present, but we do not add any to the total originally present; on the contrary a little goes off of the farm in various forms—in the increased weight of the lambs, in the case which we have already used as an illustration. The exception to this statement is in the case of the nitrogen, provided alfalfa, clover or pea-vine hay has been fed, when, owing to the fact that these plants obtain a considerable portion of their nitrogen from the air through the agency of certain organisms, we may actually return more than we took away from the soil with the crop.

The use of barnyard manure is preeminently a method of maintaining the fertility of the land, but is in a measure a method of increasing it by improving the conditions of the soil; also by adding organic matter, and in our case by increasing the supply of nitrogen.

GREEN MANURING.

The next best method is probably that of green manuring, and for this purpose we have no better plant than alfalfa. I know that there are some who may think it too big a sacrifice to turn under a good growth of alfalfa for the sake of its manurial effect upon the soil. The writer has a great deal of sympathy with this view, but it is not well supported by any facts which we can produce. There seems to be no plant which could be grown here for this purpose.

Crimson clover is, so far as I have seen, a failure with us; red clover is by no means a pronounced success, though it will grow; pea vines do not make a sufficiently early growth. Some of the vetches might be better, but they, too, are not early enough. Rye might be used if we aimed at adding succulent organic matter, which would easily decay, but would add no nitrogen or other fertilizing substance.

In green manuring we take nothing away from the soil, nor do we use the crop grown for any other purpose, but simply return it to the soil in its succulent and easily fermentable condition, together with the total content of plant food which it has gathered from the soil. The effects produced may be marked, but they are not due to actual addition of plant food, as in the case of the addition of mineral manures, but are due to the availability of the plant food contained in the crop, the effect of the fermenting material upon the soil and probably to the humus substances produced.

I have stated that alfalfa is our best plant for this purpose. It is out of the question to use this plant for this purpose, except in some systems of rotation, which is, under all circumstances, advisable, whether the last crop is to be potatoes or sugar beets. I am not prepared to even suggest what rotation will prove to be most advisable; some of our practical men can work that out in detail.

I fully appreciate the fact that a good plantation of alfalfa which will yield 3 1-2 to 5 tons of alfalfa hay per acre, is a valuable asset on a farm, but some of our people are coming to realize that it is a good thing to plow under, too, though it is not the easiest task to perform, especially when it is in full growth in the spring time.

ALFALFA OUR BEST PLANT TO USE AS A GREEN MANURE.

There are several considerations which lead me to think this the best plant which we possess for this purpose.

Our soils are only fairly rich in nitrogen, and an addition of this element from time to time is very advisable. Alfalfa is an energetic gatherer of this substance, largely from the atmosphere, the young alfalfa shoots being relatively very rich in this element. There are but few plants, even among the legumes, by means of which we can add nitrogen to the soil so cheaply as by means of alfalfa.

Alfalfa is not only an energetic gatherer of nitrogen from the atmosphere, but it is also an energetic gatherer of other plant food from the soil, so much so that a ton of alfalfa hay made from plants cut in May before any blossom buds had appeared, contained about 60 pounds of potash, equivalent to 111 pounds of the pure sulfate of potash, and whose value would be $3.00 at the price prevailing last year, while the nitrogen in the same would be worth $8.50, nearly.

EFFECTS OF ALFALFA DUE TO DEEP FEEDING.

I will here digress a little to discuss a fact which I have made rather prominent and one which may seem to some as an objection to the alfalfa. I have stated that the alfalfa plant is an exceptionally heavy feeder, which I have shown to be the case by showing that the market value of the food constituents removed from the soil by one ton of alfalfa hay, assuming one-half of the nitrogen to have been derived from this source, was $7.57 at the prices which potash, phosphoric acid and nitrogen commanded in 1904. Some persons have before now asked me how it is possible to harmonize this fact with the observed improvement produced by putting land down to alfalfa for a few years.

Both facts are well established, *i. e.,* that a piece of land which once produced 50 bushels of wheat per acre and had been so far exhausted that it would produce only 18 bushels, may be so far restored in its fertility by being put down to alfalfa for a few years as to produce 35, 40 or even more bushels per acre.

In the meantime it is very probable that an average yield of four tons of alfalfa hay has been cut annually. This land was no longer able to produce 50 bushels of wheat per acre, which, with the straw, would require not more than 143 pounds of potash, phosphoric acid and nitrogen taken together, but it would very probably yield four tons of alfalfa hay during the season, which would re quire 469 pounds of these ingredients. The alfalfa crop of four tons per season removes a trifle over three times as much of these elements of plant food as a fifty bushel crop of wheat, together with its straw, and that from soil which has been so far depleted of its supply of plant food as to no longer yield more than eighteen bushels of wheat.

I would not be too sure that I can fully explain this great difference. It is, however, no less certainly a fact than it is that such land will again produce wheat at a very greatly increased rate after it has been in alfalfa for a few years.

While I may not explain the facts in the case, I will suggest some things which are apparent. The root systems of the two plants are entirely different. The wheat plant has a fibrous system which, under favorable conditions, may penetrate the soil to a depth of four feet, but the conditions obtaining in our soils are not favorable to their attaining this depth. It is a fibrous system, one admirably adapted to gathering sustenance for the plant from rich, mellow ground, especial at no great distance from the surface, but not to penetrate hard soil to more considerable depths.

The four feet mentioned as the maximum depth to which the wheat roots may penetrate, is probably very much deeper than they, in fact, penetrate our soil, unless it be in very exceptional cases.

The alfalfa has a simple tap root system, at the best only

slightly branching, but able, in our soils to attain to a depth of from 9 to 12 feet, even through soil so firm that a pick is necessary in order to remove it. The largest, most branching portion of this root system is at the point of its greatest depth or nearly so. This system is marvelously free from fibrous roots, though under special but easily explained conditions there may be a fair abundance of what may be termed fibrous roots. For our present purpose we may waive the question of the relative ability of these two plants, the wheat and the alfalfa, to obtain food from sources which may yield it slowly or with great reluctance, and simply consider the amount of soil which they respectively lay under tribute, considering that the whole of the soil from the surface to the maximum depth attained by the respective root systems is involved. Using this assumption as our basis, we see that no part of the soil would be laid under a relatively heavier tax by the alfalfa than by the wheat, because the alfalfa feeds to a depth at least three times as great as the wheat plant. Our assumption, however, is not justified by what we know of the roots of the alfalfa, which form a cone-shaped system whose base is from 9 to 12 feet from the surface. The first few feet of the root may consist of a single tap root and cannot possibly come in contact with more than a small fraction of the soil reached by the smaller roots of the deeper portion of the system. The larger portion of the tap root near the surface, even if it is as active in gathering food as any other portion of the root system, can only gather a comparatively small portion of the food used by the plant. This justifies us in using the term so frequently heard, characterizing the alfalfa as a deep feeding plant. These considerations also justify the popular expression that the alfalfa rests the land, meaning, of course, that portion of the soil previously exhausted by the wheat. The correctness of this assertion is not in the least affected by the apparently contradictory fact, that a four ton crop of alfalfa hay removes from the soil a trifle over three times as much plant food as a fifty bushel crop of wheat, including the straw.

There are some interesting facts relative to this question, and while certain reservations ought to be made, we can still, with a fair degree of accuracy, state that the alfalfa obtains its food very largely below the depth to which the wheat root can penetrate. This explanation may not be a complete one, but it answers two questions which are frequently asked: First, Is alfalfa a heavy feeder? To which the answer is, yes. Second, How does it rest the soil? To this we offer the following answer: By feeding below the depth had in mind by the questioner.

EFFECTS OF ALFALFA DUE TO OTHER CAUSES.

We will now turn to some other facts which cannot be omitted

in considering the question of alfalfa as a green manure. Alfalfa is not a plant which can be sown in late summer or early fall with the expectation of obtaining a growth of desirable material to plow under the following spring. We can only use it as a green manure at the end of a rotation in which the alfalfa is one of the crops, and involves a longer rotation than can advisably be used under Eastern conditions, consequently it is necessary to take other factors into the account.

We have assumed that our alfalfa has yielded four tons of hay annually and we have removed from the soil a total of 469 pounds of plant food in the form of potash, phosphoric acid and nitrogen, or 369 pounds, considering that only one-half of the nitrogen came from the soil. The loss in making alfalfa hay ranges from 20 to 66 per cent.; in other words, a four ton crop of hay gathered, represents, even under the most favorable conditions, five tons cut, not counting the stubble. This ton lost is composed of leaves and the fine stems, portions richer than the average sample of hay in nitrogen and ash constituents, and representing a total of 117 pounds of plant food. This, owing to our practice of irrigating after each cutting, especially after the first and second cuttings, is almost wholly incorporated into the soil, for the moisture will facilitate its decay and the strong stubble will prevent its being washed away to any considerable extent. The stubble proper is not considered in the preceding statement, on account of which we are justified in increasing this amount, 117 pounds, to 150 pounds, which alone is as large an amount of plant food as is required to raise a fifty bushel crop of wheat. It is further to be remembered that, as we have assumed one-half of the nitrogen added came from the air and the rest of the substances from portions of the soil beyond the reach of the wheat plant, the amount of plant food added is practically a clear gain.

So far two important points have accrued to our soil by simply being put down to alfalfa, a practical resting of the surface soil, which would be still further benefited, as I firmly believe, if we could give our alfalfa a cultivating, and, second, by an addition of plant food. These are not the only points which we will gain if at the end of our rotation we turn under a good growth of succulent alfalfa, rich in nitrogen and potash. Our soils need organic matter, but coarse manure or such as has been firmly matted do not readily pass into decay under our conditions, but the green alfalfa ferments easily, exercising a very beneficent influence upon the soil, not only adding its own available plant food, but possibly acting quite vigorously upon the soil itself, greatly improving the mechanical as well as the chemical conditions. Some of our farmers have already discovered that these things are facts and do not hesitate to turn under a fine growth of alfalfa, though some still look upon it as a doubtful practice.

Some other facts at which we have arrived are of interest in this connection, *i. e.*, the actual manurial value of the stubble. On an acre of alfalfa taken to the depth of six inches it is worth, estimated in the same manner that we have estimated the manurial value of the hay, not far from $20.00 per acre, while the roots below the depth of six inches possess a value of $16.00, or the stubble and roots together have a value of about $36.00 per acre. It may be a rather difficult task to turn under a growing crop of alfalfa in middle or late spring, but it is also difficult to correctly estimate the great manurial value of the excellent material thus added to the soil; it is certainly very much in excess of the figures given above .

There is still another respect in which alfalfa is probably our best crop to use as a means of benefiting the soil. It has been intimated, though not explicitly stated, that our soils are often very firm at shallow depths, so much so that it is very probable that scarcely any cultivated plant may be able to reach the greatest depth to which it can and would feed under ordinarily favorable conditions. A good stand of alfalfa, say three years old, will probably have 500,000 plants to the acre, or more than ten plants to the square foot, every one of which penetrates the soil to a depth much greater than the usual feeding depth of such plants as potatoes, beets, wheat, etc. They not only in this way open up the soil to the attack of less vigorous roots, but fill these channels with a supply of plant food, accompanied by a mass of organic matter that by its decay may bring still more plant food into available form.

This subject of preserving and even of increasing the fertility of our soils cannot be too strongly urged upon the attention of our agricultural population.

While our soils contain a large amount of potash in the total, due to the presence of the potash felspar, the amount of the available potash is not extraordinarily large, and that locked up in the felspar is only slowly becoming available, too slowly to replace that removed by crops. Our soils are poor in organic matter and only fairly well provided with nitrogen. Our climate does not favor the formation of humus, nor do our soil conditions as a rule. The best means at our disposal to meet these conditions and to maintain our good yields are, I believe, to husband all the material available for conversion into well-rotted barnyard manure, our alfalfa, all of which should be fed, if possible, on the farm which grows it, being of great value for this purpose. All of the straw, while of itself not of very great value, can be used to good advantage and should be so used.

Our alfalfa is an excellent plant to turn under as a green manure, but owing to facts which are evident to every ranchman, this involves a certain rotation of crops, at the end of which a good, vigorous growth of alfalfa can profitably be added to the soil.